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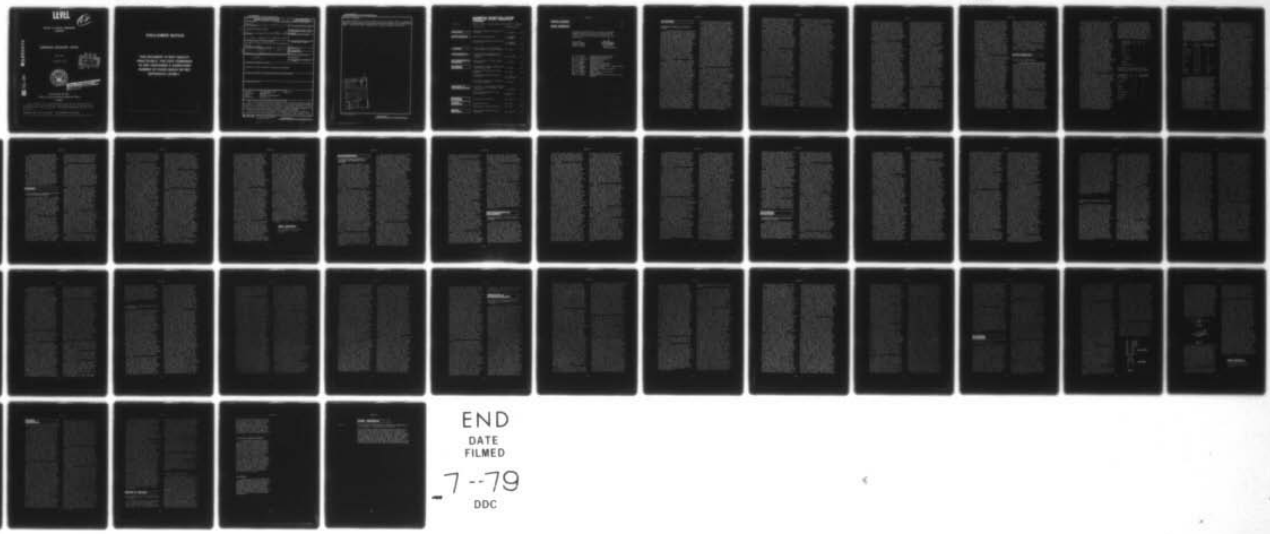

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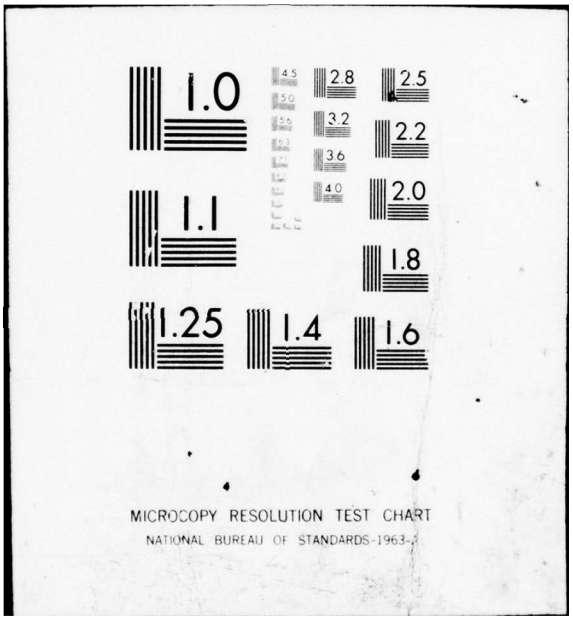
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30 April 1979

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This is a monthly publication presenting brief articles concerning recent developments in European Scientific Research. It is hoped that these articles (which do not constitute part of the scientific literature) may prove of value to American scientists by calling attention to current developments and to institutions and individuals engaged in these scientific efforts.

The articles are written primarily by members of the staff of ONRL and occasionally articles are prepared by, or in cooperation with, members of the

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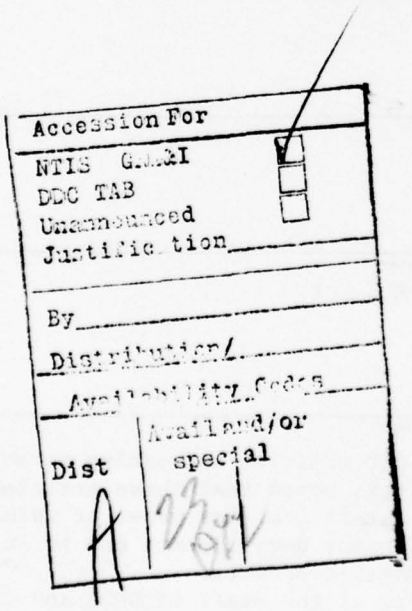
scientific staffs of the United States Air Force's European Office of Aerospace Research and Development and the United States Army Research and Standardization Group. Articles are also contributed by visiting Stateside scientists.



EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by Aubrey W. Pryce, Irving Kaufman, and Victoria S. Hewitson

30 April 1979 Volume 33, No. 4

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AVIATION

OPERATIONAL RESEARCH IN AVIATION IN BRITAIN

The aviation industry is a monstrous thing, almost impossible to manage. In the US there are at least six significant segments with management responsibility: the aircraft manufacturers, the airlines, the military, NASA (which is the National Aeronautics and Space Administration—people tend to forget the aeronautics because of the fascination with space), the FAA (Federal Aviation Administration) and the CAB (Civil Aeronautics Board). The CAB issues licenses and the like; FAA has the ATC (Air Traffic Control) system and some of the research; NASA tends to have some of the more fundamental and more expensive research, such as the wind tunnels, which (in the opinion of many people) constitute a principal reason why the US is still the world's primary supplier of commercial aircraft.

In the United Kingdom, the organization is completely different. With the exception of Independent Tour Operators ("charters") and a few smaller airlines (of which the best known to Americans is Freddie Laker's), the airlines are in one great government-owned corporation, British Airways. Most of the hardware research that in the US would be done by NASA or FAA is carried out here by the RAE (Royal Aircraft Establishment), which is part of the Ministry of Defence (although senior posts at RAE are all held by civilians). The operational aspects that correspond to our FAA are handled by the CAA (Civil Aviation Authority). An analog of the CAB really doesn't exist—since there are so few private airlines, there is no need to worry much about regulating them; the CAA does what regulating there is.

The RAE is located in Farnborough, Hampshire, a few miles southwest of London. Not much operational research is performed there—the nearest thing is a Systems Assessment Department (headed by David Humphries) in the Weapons Directorate. Here the principal interest is in using operational experiments, supplemented by simulations (but comparatively little analysis), to evaluate various alternative weapons systems that are being considered for procurement. Actually, RAE is under the Procurement (as distinguished from the Operational) Executive of the Ministry of Defence, and this colors all of its activities.

For example, staff members are evaluating certain air-to-air weapons systems by studying air-to-air combat. For this purpose they have instrumented aircraft engaged in actual mock air-to-air combat, and are using them to check a highly sophisticated computer simulation that was originally developed in the US. The simulation might include the structural and aerodynamic properties of a British fighter and a specific bomber of a potential enemy, together with actual tactics known or assumed for each. The primary outputs are such quantities as the lengths of time that the relative positions of the aircraft are favorable for firing of weapons by one of them. Using this result, it is possible to evaluate the relative worth of different weapons systems which require different minimal times for lock-on. Another interesting output is a motion picture with remarkable verisimilitude made by computing the exact position and aspect of each aircraft every 1/16 second, displaying these by computer graphics, and then running the whole thing back at 16 frames per second through an ordinary movie projector.

The CAA has a very large and active OR group called DORA (Directorate of Operational Research and Analysis). It reports directly to the Chief Scientist, Dr. Oliver B. St. John (pronounced sin-gin), who has both staff and management responsibilities. He is responsible for counseling the chairman on all scientific and engineering questions; and he is in charge of the research budget of about two million pounds.

The CAA is a "QUANGO," a Quasi-Autonomous Non-Government Organization, quite unlike the Ministry of Defence which is a government department, or British Airways, which is a government-owned corporation. It is supposed to break even financially and not be a burden on the taxpayer; remarkably, it is essentially doing so. Its annual budget is on the order of £100 million, and it collects about that much, mostly from the airlines from such things as landing fees. Its employees are not civil servants, but they have benefits similar to (and perhaps slightly better than) those of the Civil Service, and they belong to the same unions. As in many other British organizations,

unionization goes quite high up in the managerial ranks; the Director of Operational Research and Analysis, Ken Treweek, is a member of a union. (In case of a strike, as a member of both the union and management, he would be faced with an interesting dilemma.)

Treweek has two deputy directors: David Smith for "Systems" and Trevor Ingham for "Environment." Although the first-named has, as he told me, a "token group" in Management Science, they do almost no work in this area. Its major responsibilities are Air Traffic Systems (i.e., the systems aspects of air traffic control) and such things as controller workloads, airport capacities, flight scheduling (in the sense of flow control, as described below), and the major question of North Atlantic traffic (which will be the subject of a separate article).

The Environment group works primarily on safety and noise. The noise study is described below. Among the safety problems is obstacle clearance. There is an Obstacle Clearance Panel, in which CAA has been involved, which has just completed its final report after many years of study. Considerations here deal with the following: If someone wants to build a high building somewhere, and the authorities tell him he can't do so, the value of his land goes down. Thus, the maximum height which is allowed for a building at any particular distance from an airport affects the price of the land, and since most of the valuable land in the country is near some airport, such decisions can have major economic impact.

This group also partakes in a study called Review of the General Concept of Separation (RGCS), set up as a continuing study by the International Civil Aviation Organization about ten years ago. This considers all aspects of separating aircraft, except for the North Atlantic study; in the North Atlantic there is no control by land-based radars of the positions of the aircraft, and they operate under an entirely different system.

Separation between aircraft is generally measured in one of four ways, leading to four different studies and four different standards; namely, lateral, longitudinal, vertical, and horizontal. The first three apply when aircraft are on tracks or airways and determine how close an airplane may be to the airplane at left or at right, in front or in back, or above or below, respectively. The last (horizontal separation) is a special case:

Conventionally, the air traffic controller has a radar screen on which appears all of the information from a single radar. He can switch so that the information from a different radar appears, but he cannot simultaneously utilize the information from two or more radars. This has obvious disadvantages, but it also has great advantages: any systematic errors cancel out as between two planes that are being separated; that is, only relative accuracy is required in measuring the separation of two planes, not absolute accuracy. Furthermore, the controller knows what the accuracy is: the range error tends to be very small and independent of range, while the azimuth error is, of course, linear with the range and tends to be large except at very short ranges.

However, the CAA has now bought an IBM 9020 (the software being all written and the system approved by the FAA) for processing the radar data. Data from all of the radars covering England, Wales, and the Channel are digitized and sent to the Air Traffic Control Centre near London. A given aircraft may be under observation by several radars, and the computer will pick one and display its data, but not necessarily the same radar for different aircraft. The logic could even be written to combine the data from several radars for each aircraft, but this is not actually being done at the present. Thus, in the old days, if the display showed that there were two aircraft at the same azimuth, with one being two miles farther away than the other, the controller knew that both observations were being made by the same radar, and so the two aircraft surely were separated by two miles. The radar might have been in error by two or three miles, but since exactly the same error was made for both aircraft, the measurement of separation was precise. Now the same picture might come from two different radars, with errors in opposite directions, so in fact the two aircraft could be in the same place!

Before the 9020 is actually installed and starts controlling the system, a decision must be made as to what is a safe horizontal separation standard; that is, what is the minimum distance as displayed on the scope that

guarantees that the two aircraft will actually be separated and will not collide? Other groups around Europe have the same problem, but since they have different radars and different computers, they will not necessarily come up with the same numerical answer. The CAA does not at present know what this safe separation will be, but if it turns out to be as large as 5 miles the whole system will become unworkable; apparently there is considerable confidence that it will indeed be well within this limit.

The noise problem concerns the effects of aircraft noise on sleep. The decision facing the CAA (actually the decision must be made by the Department of Trade who is paying the CAA to do this study) is the permissible noise levels of aircraft at night. A comparable decision with which many Americans are familiar resulted in the prohibition of landings at National Airport in Washington, DC, after 10:00 p.m.; but that decision appears to have been made arbitrarily rather than on the basis of scientific study.

There has, of course, been an enormous amount of published research on sleep and noise, but surprisingly little that is relevant to this particular problem. It is known, for example, that sleep deprivation has significant results, but no one seems to have determined what harm, if any, is done when someone is awakened (as by a noisy aircraft) and then allowed to go right back to sleep. Furthermore, there is inadequate data on what noise levels do wake people or keep them from going to sleep, and on the insulating effects of buildings against noise (since the criteria must be established for noise level outside the buildings, while the effect of the noise is only significant inside). It appears, for example, that the noise levels inside buildings are in the neighborhood of 15 to 25 dB below those outside; it also appears that women and older people are more easily awakened by noise than are their male and younger counterparts, respectively. But, of course, both problems are enormously complicated and depend on a wide variety of factors.

The CAA noise study was described to me by Peter Brooker, who works in Ingham's group. The group wants to know how bad the noise levels are around Heathrow (London's major airport), how many people will be awakened by these noise levels, and the like. But the interest seems to be primarily in how many people will complain. The study is being based largely on questionnaires, some distributed by mail and others administered in person. There is a surprising difficulty in interpreting the results of these questionnaires: It seems possible that people might wake up anyhow and only complain if they happen to hear an airplane at the same time. Thus, it is not enough to know that a person claims to have been awakened by an airplane unless one can find out somehow how often the person wakes up without airplanes!

David Smith described the scheduling problem to me, and while "scheduling" is one of the standard techniques in operations research, this problem, which really concerns flow control, is quite different. Most of the major air routes in Europe funnel through France; e.g., almost all flights between Britain and southern or eastern Europe, together with all flights between Spain and the rest of Europe, or between Scandinavia and Italy, etc. Since the French cannot handle all this traffic safely, they restrict the number allowed—for example, 10 per hour from the UK to Spain (and beyond) and another 14 per hour to southern France, Italy, Greece, and North Africa. Only the planes flying above 33,000 feet (i.e., some of the transatlantic aircraft flying over Britain and France to places in Europe) are exempt. The French transmit these limits to the Air Traffic Control Centre in London, and the latter is responsible for holding up aircraft, if necessary, to maintain these rates. The result is delays, averaging 15 to 19 minutes per plane over the three busiest hours, 9:00 to noon.

On a bad day, of course, these delays can build up to much more than the average, so that the CAA has determined to try to correct this problem. A basic cause of the difficulty is that almost everybody wants to take off at 9:00 a.m., and this pulse in the system builds up a queue that doesn't work off for hours. Trying to get some airline to move to a different time is a nonzero-sum game, and therefore difficult. Rather than telling people what they have to do, the CAA requests six-month notices of schedules, then simulates these schedules and predicts the

resulting delay times. It is then up to the operators to live with, or reduce, these delays. This works moderately well. The Independent Tour Operators seem willing to accept a "grandfather" logic that if a particular operator has had a certain take-off time he is allowed to continue it. The problem is that nobody wants to move his time. The OR people at CAA have found that the utility of a one-minute unscheduled delay is about equal to that of a three-minute scheduled change; that is, the airlines appear to be willing to accept a twenty-minute delay on a 9:00 a.m. scheduled take-off as equivalent to no delay on an 8:00 a.m. scheduled take-off. Furthermore, there is no penalty to an airline that fails to cooperate. If some operator who has not filed six months in advance comes in for take-off, he gets the same place in the queue (with its first-come-first-served logic) as an operator who has been cooperating.

There is another scheduling problem involving congestion in landing and take-offs at Heathrow, but this is a conventional problem familiar around the world. At Kennedy or O'Hare the peaks occur around 6:00 p.m.; at Heathrow, they tend to occur in the mornings, partly because most of the transatlantic traffic arrives then. On an average good day in summer there are 31 arrivals per hour, resulting in average delays of about five minutes; but if the number of arrivals should increase only slightly—say to 100 in three hours—the average delay goes to 20 minutes, and obviously under some circumstances things could get a good deal worse.

These numbers assume that the demand stays steady. Actually, demand has historically grown at a rate of about 3.5% per year, and is expected to continue to do so in the future. (There has been a minor "hiccup" in this growth pattern because of the increase in the price of oil starting in 1973, and this has led to a flat demand between 1973 and 1978, but it has now started to grow again). Increase at 3.5% per year means doubling in 20 years. A lot of people have been worrying about this. There was the famous "Third London Airport Study" (Gatwick is the second London airport) which was inevitably heavily criticized (nobody wants an airport in his own neighborhood). Some of the most severe criticisms of the report were reserved for the cost-effectiveness parts of the study, with the result that the OR community is now somewhat gun-shy regarding this project. There will doubtless eventually be a third airport, and the CAA is involved in this decision, but it will now apparently go rather slowly. Meanwhile, the CAA is also involved in a study concerning a fourth terminal at Heathrow. There are clearly no good solutions to this problem of crowding the airways and the airports, but the OR people can at least quantify some of the alternatives and the penalties which may result if the optimum alternatives are not chosen.

The North Atlantic Study, which is a concern of many organizations on both sides of the Atlantic as well as the CAA, will be the subject of a later article. (Robert E. Machol)

ELECTRONICS

OPTICAL SELF-SCANNED ARRAYS

The Combined Programme of Meetings of the Institution of Electrical Engineers (IEE) and the Institution of Electronic and Radio Engineers (IERE) shows that these two organizations are doing a splendid job in trying to keep engineers and users of technology up-to-date on developments in electronics. In addition to many talks by individual speakers, the Programme lists a number of all-day colloquia, which are usually a good mix of tutorial, research and development, applications, and state-of-the-art appraisal papers, presented by university and industrial laboratory personnel. This is a report of such a colloquium, sponsored by IERE, which dealt with optical self-scanned arrays, more commonly called focal plane arrays (FPA) in the US.

The colloquium was held on 16 January 1979 at the venerable Royal Institution of Great Britain. For individuals living outside of the London area, 16 January 1979 turned out to be a rather unfortunate date, for it was one of the days of a series of Tuesday/Thursday railroad strikes. About one fourth of the registrants were therefore unable to attend. Even Prof. A. Pugh of the University of Hull, the program organizer and Chairman, could not be present. The 35 who were able to attend, however,

found it very worthwhile, with the "good mix" mentioned above well presented.

The person chosen to survey the field was Prof. J.D.E. Beynon [Univ. Wales Institute of Science and Technology (UWIST) Cardiff] who could speak with direct knowledge, for prior to joining UWIST about a year ago he had been at the Univ. of Southampton, where he was engaged in the fabrication of charge coupled devices (CCDs). He told us that his present work deals more with the use of such devices, primarily for signal processing applications.

In his talk, Beynon presented operating principles and relative merits of four types of FPAs: Photodiode arrays with bipolar and metal oxide semiconductor (MOS) addressing, CCds, charge-injection devices (CIDs), and CCD-accessed photodiodes. Topics ranging from charge generation and collection to 2-D array transfer techniques were covered in some detail. For example, he discussed blooming, the phenomenon of sensing a bright point as a small bright circle. This occurs when an intense light source produces excess charge that overflows from the potential well in which it is collected into potential wells adjacent and beyond. A remedy is an "overflow drain diffusion," another the use of photodiode sensing and CCD read-out. It was of interest that even though buried-channel devices are commonly used in the UK, Beynon did not refer to these.

The next speaker was David J. Purll of Sira Institute Ltd., a nonprofit organization of around 100 scientists and technologists headquartered near London. Sira operates internationally in research and development activities relevant to industrial instruments and control equipment. Readers may know of this organization through its publication *Measurement and Automation News* and monographs such as *The American Market for Scientific and Industrial Measurement*. Purll stated that linear arrays (typically of 1024 elements 30 μm center-to-center) are used heavily in industry to make dimensional measurements, e.g., in determining the diameter of glass fibers or examining objects on a conveyor belt. Tinplate inspection, where the detection of small black spots on a highly reflective surface is desired, has also been tried. However, to date, because of their better resolution, laser scanners are being used in this role. Two-dimensional arrays have been used in spacecraft star sensors. Purll pointed out that pattern recognition using arrays and microprocessors looks promising and that in particular, Pugh has used this combination to inspect small components to be used on an assembly line. The following comparisons among FPAs, and of FPAs with TV and laser scanners present Purll's perception of the state-of-the-art, where CCD, SSPD and CID represent charge coupled device, solid state photodiode,

CHARACTERISTIC	CCD	SSPD	CID
Element Size	-	+	+
Noise	+	-	-
Dark Current	-	+	+
Clocks:			
Complexity	-	+	-
Criticality	-	+	+
Blooming	-	+	+
Surface Structure	-	+	-

and charge injection device respectively, and + indicates a relative advantage, and where 1 is better than 2.

CHARACTERISTIC	FPA	TV	LASER SCANNER
Size and Weight	1	2	3
Power Supply	1	2	3
Life	1	2	3
Geometry	1	3	2
Spectrum	2	1	3
Linear Response	2	3	1
Scan Pattern	2	3	1
Uniformity	3	2	1
Price	2	1	3

Purll feels that applications of FPAs are device-process-limited rather than design limited and that steady progress rather than rapid breakthroughs will be realized in device processing.

David J. Burt of the GEC Hirst Research Centre, Wembley, Middlesex, presented the following rather thorough comparison of nine companies' current capabilities. Here the asterisk indicates the use of an anti-blooming technique, and FT, ILT and RG refer to frame transfer, interline transfer and resistive gate, respectively.

COMPANY	TV LINES	TRANSFER TECHNIQUE
RCA*	320 × 512	FT
Texas Instr.*	800 × 800	FT
Texas Instr.*	327 × 490	FT
Fairchild	380 × 488	ILT
GE*	248 × 244	CID
Philips*	200 × 200	RG
GEC*	240 × 300	FT
Sony*	142 × 492	Zig-Zag ILT
Hitachi*	384 × 485	MOS-D
Toshiba	340 × 512	FT

It will be noted that GEC is listed as a manufacturer of FPAs. Burt therefore spoke from the experience of a group that has been involved in FPA development. Based on this experience, he listed the major areas in image sensor development as manufacturing yield, dark current and its nonuniformity, nonuniformity of photoresponse, blue sensitivity, and blooming control. The major defects found during device manufacture are current leakage (so-called dark current spikes) and smearing, caused by defects in photoresists. Burt stated that a good device today can achieve a peak signal-to-noise ratio (in output current) of about 100, has a responsivity of 2 mA/lumen, and saturates at about 500 nA/cm^2.

With all the development in FPAs, the question often asked is how soon will these devices become competitive with high quality vacuum-type TV cameras. Burt's feeling is that it would be another 10 years before the British TV networks' requirement of ±0.5% in uniformity could be met. The feeling at GEC, in fact, is that although FPAs are not competitive with present-day camera tubes, they are opening up new device applications. An example is operation of TV cameras in mines, where the high voltage required for vacuum vidicon operation cannot be tolerated.

Dr. Ian Childs of the British Broadcasting Corporation's Research Department discussed efforts at using FPA for conversion of film into TV signals ("color telecine"). Since the film can be moved at constant speed here, the use of linear arrays is satisfactory. Buried channel CCDs operated at a high clock rate are needed, since the sensistivity variations in the slower-clocked photodiode arrays cause disturbing vertical stripes. In the system described, a dichroic filter/beam splitter separates the red, green and blue components of the image and directs each color channel to a 1024 element linear array. The bandwidth of each color channel is about 50 nm. Signal-to-noise ratio varies from 72 dB in the red channel to approximately 50 dB in the blue. Childs mentioned, in passing, that film exposed at 24 frames/second must be shown at 25 frames/second, in order to be compatible with the British TV frame time. This raises the audio pitch by about a half semitone and results in a 4% time compression. While the increase in audio frequency could only be noticed by a person with a perfect sense of pitch, there is a time compression of approximately 2.5 minutes for every hour of show time that must always be planned for. [British TV and why it is better than that in the US was discussed in these pages some time ago by Blachman (*ESN* 31-11:445).]

One of the limitations in the performance of all FPAs is nonuniformity in pixel-to-pixel response. This problem is caused by variations in carrier lifetime built into the silicon when grown and while the device is being processed from the raw silicon. A technique for enhancing the uniformity of response of FPAs was described by Peter W. Fry (Integrated Photomatrix Ltd., a small company in Dorchester, Dorset, UK, that has its own semiconductor device fabrication facilities and specializes in optoelectronic devices and instrumentation). Pixel-by-pixel setting

of the gain of the sensor/amplifier combination under the control of a programmable read-only memory (PROM) has provided a uniformity of signal to better than ±1%, which is an order of magnitude improvement over the uncorrected signal. A device using this technique has been developed for quality control of the printing of Danish currency. As this currency is printed in a continuous roll of two side-by-side bills, a differencial approach is used to detect flaws by comparing outputs from two linear arrays with PROM-controlled gain.

Even though pyroelectric array and FPA technologies are very distinct, a presentation of some recent applications of pyroelectric linear arrays was made by S.G. Porter (The Plessey Company Ltd., Allen Clark Research Laboratories, Caswell, Towcester, UK). These arrays are made from a Plessey-developed ceramic that has a Curie temperature of 220°C.

(As an aside, it was noted that a major use of Plessey's single-element pyroelectric detector has been the heat-sensitive element in burglar alarms which are often used in the US.)

A device developed for studying rocket plumes has as its sensor a 32-element array with the following characteristics:

Element size	1 mm × 0.2 mm
Response band	7 to 15 μm
Sensitivity	360 V/W
NEP	$2.8 \times 10^{-10} WHz^{-0.5}$
Responsivity uniformity	±10% element-to-element

(NEP is the minimum detectable power for input bandwidth of B Hz and post detection bandwidth of 1 Hz.)

Another array, used as the detector in a grating spectrometer, had a responsivity of 10^6 V/J and responsivity uniformity of ±2%. Porter stated that Plessey is currently planning to mate a pyroelectric array detector with a CCD readout. He predicted that within 5 to 10 years solid state pyroelectric images would have the response found in present pyroelectric vidicons.

Helmet mounted sights and helmet position sensors are being used in an increasing number of fighter aircraft in both the US and UK. Dr. M.D. Stephenson (Marconi Avionics Ltd., Rochester, Kent, UK) described the Marconi approach to helmet-position sensing. This uses three light emitting diodes (LEDs) mounted on each side of the helmet and a 1024-element linear-array "camera" mounted on each side of the cockpit. By: 1) using a narrow bandpass filter centered at the LED emission wavelength of 945 nm; 2) pulsing the LEDs; and 3) implementing a sunlight subtraction technique, they have been able to achieve an angular helmet position accuracy of 0.5° to 1° and an unrestricted field of view of ±180° in yaw, ±70° in pitch and ±30° in roll.

In summary, while, according to Burt, "The British usually go to the US to determine the state-of-the-art in optical self-scanned arrays," it is quite obvious that several research and development laboratories in Britain are improving the performance of FPAs and using them to solve a wide range of problems.

(During preparation of this article we learned of a comprehensive text entitled *Solid State Imaging*. Edited by P.G. Jespers, F. van de Wiele, and M.H. White, it covers a NATO-sponsored Advanced Study Institute on this subject held in Louvain-la-Neuve, Belgium, in September 1975. The publisher is Noordhoff International Publishing, Leyden, the Netherlands, and Reading, MA.) (Richard S. Hughes and Irving Kaufman)

MICROWAVE SEMICONDUCTORS ON THE LIDO DI VENEZIA

The US and Japan are not alone in efforts aimed at replacing microwave tubes with solid state devices. Europe has been active in this area for a long time. In fact, Dr. Cyril Hilsum of the Royal Signal and Radar Establishment (RSRE), Malvern, UK, is looked upon by many as the godfather of much of the device-oriented work with III-V compounds in the West. Moreover, The Plessey Company Ltd. currently claims to fabricate the best low-noise microwave gallium arsenide field effect transistors (GaAsFETs).

To further this work, small groups of researchers have met annually since 1972 (except for 1976) to discuss problems and progress in this field. This

is a brief note on the latest of such meetings, the 5th Specialist Workshop on Active Microwave Semiconductor Devices, held in October 1978. The Hotel Des Bains, on Lido di Venezia, one of the islands in the bay at Venice, was ideal for this workshop. Since the tourist season had concluded six weeks earlier, there were no diversions on the island to detract from participation in the workshop. On the other hand, nearby Venice kept spouses happily occupied during the day and beckoned to everyone to enjoy its treasures after the working sessions. Perhaps the only hitch was that a few of the participants were delayed for several hours by one of the so-called hiccup train strikes that sometimes occur in Italy.

Organized on a rather informal basis by individuals from several countries and sponsored this year by CISE SpA, an Italian research organization in Segrate, near Milan, and by the US Army European Research Office, the workshop was attended by 54 individuals. The UK contingent was the largest, followed closely by that of Italy, with smaller groups from West Germany, France, Ireland, Hungary, Sweden, Japan, and Austria. Except for the writers, the only representative from the US was Dr. Daniel R. Ch'en, of the Rockwell International Science Center, Thousand Oaks, CA, whose group is well known for its work on ion implanted GaAsFETs with Schottky barrier gate structures (MESFETs).

Among the organizers were J. Magarshack of LEP, the Philips-owned organization in Paris; H. Thim, of the Technical Univ. in Vienna; H. Hartnagel, who had just joined the Technical Univ. in Darmstadt, FRG, after a number of years at the Univ. of Newcastle upon Tyne, UK; P. Weissglas, of the Royal Institute of Technology, Stockholm; and G. Fabry and V. Svelto, of CISE SpA. Not all groups working in the field in Western Europe were represented at the workshop. For example, it is known that AEG-Telefunken is developing microwave transistors, but no representative from that firm was present. Subjects discussed were Material and Device Technology, Diodes, MESFETs, MOSFETs, and Circuits. It could be argued that these subjects were already well covered in the European Microwave Conference and the European Solid State Device Research Conference; so "why have a specialist meeting?" According to the organizers, the more formal conferences are generally limited to papers dealing with finished work; the workshop allows a discussion of work in progress. In addition, the workshop had papers both on devices and how they are used in circuits, while the two conferences discussed either one topic or the other, but not both. In addition, the multiple sessions of the more general conferences, which serve to inform on a number of subjects, do not allow the concentration possible in a workshop.

Most of the papers presented could be termed "state-of-the-art." The one real exception, and perhaps the most significant because it pointed the way toward the future, was a paper by G. Salmer (Université de Lille, Villeneuve d'Ascq, France) entitled "Simulation of very short gate FET including steady state electron dynamics effects." With the higher packing densities of devices on a chip and higher speeds of device operation, a point is reached eventually at which the transit time of electrons through a channel becomes of the order of the electron energy relaxation time. This means that the average electron velocity at a given time depends not only on the electric field but on the average electron energy as well. Not only is the ordinary concept of conductivity then no longer valid, but overshoots in electron velocity above saturation values become possible. Moreover, since only a small number of electrons exist in a channel at any one time, diffusion effects cannot be calculated in the usual classical manner. Specific conclusions from this paper were that for an FET the ratio of transconductance to gate capacity, g_m/C_g, varies as the reciprocal of gate length and that when relaxation effects are accounted for, g_m/C_g is increased. Results were given for Si and GaAs, but without taking into account electron transfer in GaAs.

Among the other subjects treated were the preparation and evaluation of GaAs epitaxial layers; ion implantation for microwave devices; Baritt, Impatt, and Trapatt diodes and circuits; GaAs MESFETs and MISFETs, submicron gate technology; and devices for gigabit logic.

Readers interested in more detailed information are referred to the ONRL report entitled "Fifth European Specialist Workshop on Microwave Active Semiconductor Devices," which will shortly be available from this office.

The workshop can be summarized by stating that although some of the papers had also been presented elsewhere, some new results were given here. The informal aspects of the workshop allowed close communication between speakers. It was evident that, in general, Western Europe is behind the US and Japan in the fabrication of microwave devices. However, a number of laboratories are trying to catch up and to fabricate and develop commercial products of their own.

Finally, it is again worthwhile to point out that the paper by Salmer, which ventured into a new area, may be considered the precursor of much activity in a new semiconductor field in which the classical semiconductor concepts such as conductivity and diffusion may no longer hold. (Irving Kaufman and Alfred K. Nedoluha)

ENERGY

A JOULE SAVED IS A JOULE EARNED—SWEDEN TACKLES ITS ENERGY PROBLEMS

As we all know, Sweden is a highly industralized country. It is relatively small with only 8 million people. Also it has neither coal nor oil resources so that much of its energy comes from imported fuels. The distribution of the Swedish energy supply is interesting: Oil 72%, hydropower 12%, wood and waste 8%, coal and coke 4%, and uranium 4%. It is obvious that Swedish dependence on imported oil is dangerously high; this was brought home to them in the 1973 oil crisis, and they have not forgotten.

One solution might be to create a nuclear energy system, and steps in this direction have been taken. However, in Sweden, as elsewhere, public uncertainty about nuclear energy has increased substantially and is now an important and divisive political problem. In fact, a recent government fell on this issue. There is general agreement in Sweden that energy problems are serious, and one finds strong support for the energy program. The first three-year program (1975/78) was funded at $85,000,000. It had a broad research character. At present there is another three-year program (1978/81) funded at $183,000,000. It tends to concentrate on a smaller number of development problems while still continuing a research base. The expectation is that major innovations will be introduced in the Swedish energy economy in the next three-year program beginning in 1981.

My principal interest when visiting in Sweden was the program in energy conservation which will be described in more detail later, but let me first sketch for completeness the areas of major activity in their program. The single largest item in the current budget for energy research and development is Wind Energy. They are concerned with large wind-power plants connected to the national power grid. Horizontal shaft turbines at the 50-kW level are being completed, and activities are now being focused on construction and evaluation of at least 2 full-scale units in the 2-4-MW range.

The next largest effort is in domestic fuel sources. Here the major emphasis is on methods for utilizing sunlight through cultivation of plants. The projects are primarily concerned with forestry energy since Sweden has extensive forests. Studies are being made of the use for energy purposes of naturally growing forests, energy plantations of fast-growing trees and forestry residue and waste. These studies extend to methods for the utilization of biomass and its conversion to fuels, heat, and electricity. A recent article by Sohn (*ESN* 31:10-398) describes some parts of this program in more detail.

Industry accounts for slightly over 40% of Sweden's total use of energy, more than half of which is in the wood, pulp and paper, and iron and steel industries. One of the more novel research studies in the wood and pulp area is concerned with the use of "white rot" fungi to aid the process of breaking down wood into pulp. Another study, which makes extensive use of the scanning electron microscope, attempts to determine the role played by water in pulp fibers at the micron level and to discover ways of pressing out more of the water thus reducing the energy needed to dry the pulp.

There is a special program devoted to assessing future possible applications of heat from the outside to the inside of a building. One set of projects includes attempts to utilize heat

sources other than air, such as soil heat, waste heat, and heat from subsoil, surface, and drain water. There are also tests on the use of diesel engines to power heat pumps; in this case the diesel engine itself can contribute as a heat source!

In the field of transportation the effort is two fold. One set of studies is concerned with systems of transportation for goods and for people. The aim is to provide a basis for assessing alternative transportation systems feasiblities in the long run, using less energy than today's systems. Particular interest is being paid to ways and means needed to produce, in practice, a changeover to such systems. More tangible activities are concerned with the introduction of methanol as a fuel since it could be produced from Sweden's forests. It has been shown that 20% to 25% of methanol could be added to petrol and used in present automobiles with no adjustments except the replacement of some gaskets with material that is insoluable in methanol. Engines that can be simply adjusted to use either methanol or petrol are also under development. For the long term there is interest in the development of alternative heat engines, such as the Stirling engine, to replace the internal combustion engine.

Approximately half of the Swedish use of energy is in buildings, and they feel that extensive opportunities exist for energy conservation in this area. The idea of insulating buildings is not new in Sweden. National building codes concerned with energy loss have existed for a long time; one finds double-pane windows everywhere in Sweden, for example. On 1 January 1977 new regulations came into effect governing the insulation of new buildings. For this purpose Sweden was spilt into 4 zones from North to South with the most stringent regulations in the north, of course. For the Stockholm area the thickness of mineral wool insulation in the roof of houses was increased from a minimum of 15 cm to 25 cm. Insulation in outside walls increased from 10 cm to 15 cm. Windows will now have to be 3-pane with at least 2 panes hermetically sealed. Window size is limited and depends on the size of the room being illuminated. With the energy loss through the walls and roof much reduced, other energy losses become important. Air leakage, which may account for 30-40% of the energy loss of a well-insulated house, is considered for the first time and assigned maximum value. For an external door or window, for instance, the specification is that no more than 1-7 m^3/m^2h pass through under a pressure differential of 50 Pa. Simple test equipment has been developed and is being issued to housing authorities which allows an inspector to measure the air tightness of a new home in about an hour's time.

In addition to the rigid specifications on new buildings, there are strong incentives to reduce the energy loss of old ones. Information is widely distributed on the energy saving and cost of various steps that can be taken in existing buildings. There are government grants and low-interest loans which help in part to pay for improvements in insulation both for individual homes and for larger buildings such as apartment houses and industrial structures.

Sweden is fortunate in that several of its best engineering schools have long had groups interested in building research. At the Royal Institute of Technology in Stockholm Dr. F. Peterson heads a Heating and Ventilation Division in the Mechanical Engineering Department and Dr. A. Elmroth is the acting head of the Division of Building Technology in the Civil Engineering Department. Peterson's group has a 30-year history behind it. There are other groups throughout the country that also serve to lead in the development of building research which is now heavily engaged in energy related studies. Elmroth, for instance, worked out in detail how a single home could be constructed using polyethylene sheet for airtightness. The toughest problems are at corners, between floors, and around windows. A series of model houses was built and tested; the air leakage was only about 1/4 of the new standards. Under these conditions ventilation is provided by exhaust fans. This, in turn, allows much greater control. Air is normally exhausted from the kitchen and bathroom. Rooms that are unused, such as bedrooms during the day, need not be ventilated then. Furthermore, the control of ventilation allows the incorporation of a heat exchanger so that incoming cold air in a duct can be warmed by the exhausted warm air.

Windows are being studied on a combined engineering and architectural basis. Heat losses of 4-pane windows

are being evaluated with the hope that larger windows can be used without increasing the heat loss so that more of the precious winter daylight may brighten Swedish homes. Windows have important psychological effects since they influence concepts of spaciousness and beauty. In addition there are the more tangible problems of acoustic transmission, heat loss, and indoor climate to which they contribute.

Groups of houses have been constructed and are being studied. In one design four houses are grouped together in a square with each having an interior glassed-over patio that provides solar heating for hot water, light, and a sun-warmed outside play area. In practice it has been discovered that for a family of four the energy need for the house is more than anticipated—the outside doors are opened a lot, as any mother of small children would have known!

A special item in the budget assigns about $2,500,000 for the construction and evaluation of many energy saving features in practice. In a building development with nearly identical construction some 26 houses are each being fitted with 40 sensors to relay to a central computer facility parameters affecting the use of the house and its energy losses. Different houses will include different energy saving features such as solar panels, heat exchangers for exhaust gases, individual thermostats on each radiator, heating by heat pumps, and so on. Each house will be occupied by a family of four people. The attempt will then be to determine which features make a real difference in actual use. With over 1000 sensors pouring information into the computer's memory banks, a major problem will certainly be to keep the engineers from drowning in the data.

An energy group has been organized to keep in contact with the man in the street who is often the weak link in saving energy. With pamphlets sent to homeowners and newspaper advertisements, they keep the need for energy conservation well publicized and offer tangible suggestions. They point out that having an oil burner cleaned and adjusted can raise its efficiency from 60% to 75% and pay for the service costs in less than a year. They try to get people to reduce the temperature of homes from the present average 73°F to 68°F. Public buildings, by law, are kept at the lower figure. At night, home temperature of 64°F is recommended. To help with this goal, they will send to any requester a card with three liquid-crystal color displays to hang on the wall. Each display changes color from blue to green to brown in a slightly different temperature range so that the room temperature can be assessed within about 1°F at a glance. Bought in bulk, these displays cost about $0.35. People are exhorted to turn radiators down rather than open windows when a room is too warm. The high cost of heating water is explained with the admonition not to wash dishes under running hot water. They have discovered also that home owners are more responsive to energy saving suggestions than apartment dwellers. This probably arises from the fact that the homeowner pays directly for his energy usage; in an apartment complex the energy charges are part of an assessment averaged over all the residents, and individual virtue is not so directly rewarded.

There is one other Swedish energy institution that is worth noting. Even a small city will have an engineer on the staff who is trained in building techniques and energy problems. He will not only inspect new buildings but he is also available as a source of expert and impartial advice for homeowners and business men who are considering reducing their energy consumption. For a homeowner he will even help prepare the forms for the government grants and loans.

All in all, Sweden seems to be tackling its energy problems with imagination and well thought through programs adapted especially to resources and needs. Furthermore, the effort seems to have the wholehearted support of both the government and the people. Its progress should be well worth watching. (Clifford C. Klick)

ORNL REPORTS

See the back of this issue for abstracts of current reports.

ENGINEERING

LA ESCUELA TECNICA SUPERIOR DE INGENIEROS DE TELECOMUNICACION EN BARCELONA

Madrid has had a Higher (i.e., five-year) Technical School of Communication Engineers since the late 1930s. Spain's second such school was established in 1971 in Barcelona. (In the same year Polytechnic Universities were set up in these two cities as purely administrative organizations loosely uniting all of their Higher Technical Schools.) Both Schools have 28 full professorships, but only 10 of these have so far been filled in Barcelona, where the faculty now includes an equal number of associate professors, twice as many assistant professors, and another 80 in the untenured ranks (cf. D.K. Cheng, "What's in a Title?," *ESN* 30-7:303).

While the present curriculum (adopted in 1975 and 1974, respectively) is basically the same for both Schools, it is taught by a younger faculty in Barcelona and, hence, with perhaps greater enthusiasm and a more up-to-date approach. Twenty-five of its members have Spanish doctorates, and, of these, a dozen also have earned doctorates abroad or have spent over two years doing research abroad. Barcelona has one faculty position (outside of the regular curriculum) that Madrid lacks: a professorship of Catalán. This language ranks equally with Castilian Spanish at the School in Barcelona. The School's Director, Carlos M. Angulo, is a native of Madrid who earned advanced degrees at the Polytechnic Institute of Brooklyn and taught for two decades at Brown University before accepting this position in 1975. He is studying Catalán so that he can fit in better. Nearly all of the 2500 students come from Catalonia, and the graduates, who so far number about 150, generally find employment in this region, as Spain's consumer-electronics industry is almost wholly concentrated in Barcelona.

About two dozen of the students are candidates for the degree doctor ingeniero de telecomunicación, which requires, in addition to a thesis, two years of courses beyond the five (and graduation project) needed for the ingeniero degree. As of 1978 the School in Barcelona had awarded only seven doctorates.

My host during a visit to the School last year was Assoc. Prof. Aníbal R. Figueiras-Vidal, who subsequently won the competition for a full professorship at the sister school in Madrid (cf. I.M. Bernstein, "The Tenure Process in Spain: A Labor for Hercules," *ESN* 32-3:97) and is presumably now a member of the latter's Communications Group. Figueiras' interests cover a wide range of topics in the field of signal theory. Together with his colleagues José B. Mariño Acebal and Miguel Ángel Langunas Hernández (also in the group that Figueiras, Marino, and Lagunas hope will before long become the Department of Signal Theory), he wrote three papers for the October 1978 Congress on Speech (which included sessions on signal theory, transmission, etc.) held in Madrid under the sponsorship of the Consejo Superior de Investigaciones Científicas.

One of these papers calculated the mean-squared error in adaptively digitally controlled delta-modulation transmission in the presence of noise, another offered a lower bound for the product of certain measures of a digital signal's bandwidth and its duration, and the third dealt with a new form of irrecursive (finite-impulse-response) digital filter for the detection and classification of transients occurring, for example, in an electroencephalogram. In cooperation with a neurological hospital, this filter has been used successfully for the recognition of epileptic spikes, thus permitting the determination of the level of medication necessary for alleviation of seizures. The filter is designed to have an impulse response corresponding to the eigenvector of the spike waveform associated with the largest eigenvalue. Spikes are categorized on the basis of the magnitude of the filter's output and the length of time during which it exceeds a threshold.

Other work of Figueiras concerns the error probability for binary signaling in the presence of noise plus the worst interference (*IEEE Trans. AES*, July 1978) and the false-alarm rate for a "rank quantizer" when the input samples form a Markov chain (*ibid.*). These papers represent only minor contributions, but they demonstrate a vigor and a breadth of interest that will surely stimulate the development of signal theory in Spain. Another recent paper of Figueiras et al. described a direct approximation technique for designing digital irrecursive equalizers with simultaneous specification of magnitude

and phase; it was written for the September 1978 European Conference on Circuit Theory and Design in Lausanne, Switzerland.

The foregoing research work and instruction in its field fall within what the School calls the Communication and Transmission Area, which also includes work on optical-fiber transmission in collaboration with the Centre National d'Etudes des Télécommunications, Lannion, France, and studies regarding a satellite relay in association with the Politecnico di Torino, Italy. The School has, in addition, three other Areas: Electronics, Switching and Data Processing, and Electromagnetics.

The Electromagnetic Area includes a Radio Astronomy Group, headed by Angulo, which is observing extragalactic radio sources to determine their variability, polarization, and relative movement. This program is carried out in collaboration with people at the Instituto Nacional de Tecnica Aerospacial Esteban Terradas INTA-NASA station in Madrid (with a paraboloidal antenna of 64-m diam.), MIT, and the Goddard Space Flight Center. The observations utilize extremely-long-baseline interferometry also involving the 36.6-m Haystack antenna at MIT and the 25.6-m antenna at Onsala, Sweden.

The Electronics Area includes, among other smaller labs, the Bioengineering Laboratory, which is headed by J. Galván. In collaboration with industrial companies and with a number of hospitals, it carries out an interesting variety of studies, e.g., measuring the vinegarization of wine or recording the electrocardiograms of fetuses in the womb. Blood flow is measured by means of the Doppler shift it induces in 5-MHz ultrasonic waves coupled from a transducer to the surface of a patient's arm, etc., through a gel; and a 2-MHz acoustic transducer is used for cardiac auscultation. Collaboration with industry and with other outside organizations pervades the research of all of the groups at the School, and it appears to have a very beneficial effect.

In past decades, university-level teaching in Spain was only a part-time occupation, and faculty members were on the campus only to deliver their lectures; they required other employment in order to have enough income. Happily the situation has now changed considerably; the vast majority of the School's faculty is there full time, and they are eager to receive visitors from abroad. Another change has been the elimination from the earlier curriculum of religious training and of "formación del espiritu nacional" (training to be good Spaniards).

The School has grown very rapidly since its beginnings in the town of Tarrasa, 11 miles northwest of Barcelona in 1971. In 1974 it moved to old, deteriorating buildings in the center of Barcelona, which soon became unusually overcrowded, with only 17 ft^2 per student. The School is now in the process of moving to prefabricated structures in the Zona Universitaria in Pedralbes, on the west side of the city 3 miles from the center, at the end of one of Barcelona's subway lines.

Carlos Angulo having succeeded in becoming and remaining the School's second Director (following Ricardo Valle) would like to turn this job over to someone else, but being greatly senior in years (57) to the others, he has not yet found a suitable successor. It is to be hoped that, when the move to the new location is completed, he can rectify the School's serious shortage of equipment for laboratory classes and its paucity of library books. Its library is, however, well supplied with journals, and its faculty exhibits the enthusiasm needed for overcoming many obstacles. (Nelson M. Blachman, GTE Sylvania Electronic Systems Group, Mountain View, CA)

ENVIRONMENTAL SCIENCES

LIDAR MEASUREMENTS AT THREE GERMAN INSTITUTES

The use of optical radar, often referred to as lidar (light detection and ranging) for atmospheric investigations is used extensively by three laboratories in Bavaria: The Projectgruppe für Laserforschung der Max-Planck-Gesellschaft (PLF) in Garching, Institut für Atmosphärische Umweltforschung (IAU) in Garmisch-Partenkirchen and Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt eV (DFVLR) in Oberpfaffenhofen. A lidar is fundamentally the optical equivalent of a microwave radar instrument. The transmitter is a pulsed laser, and the receiver consists of a

telescope, optical detector, and electronics for data acquisition and processing. Uses include determination of cloud height and structure, aerosol profiles, gaseous pollutant concentration profiles, and wind velocity (see *ESN* 33-2:66).

Professor Dr. H. Walther of the PLF (also of the Physik Sektion Universität München) became involved in lidar work several years ago when he was at the Univ. of Köln. While there, together with Rothe he performed the first long-range gaseous pollution measurements using a differential lidar technique to measure ambient NO_2 concentrations of 0.2 ppm at a range of 4 km. Differential absorption lidar (DIAL) was developed by Dr. R. Schotland (currently at the Univ. of Arizona, Tuscon). In this method the laser transmitter is tuned on and then off an absorption line for the particular gas under study. Mie aerosol and also Rayleigh molecular backscattering provide the radiation necessary for a lidar measurement. The concentration as a function of range can be calculated from the two backscattered signals. The measurements in Köln were made with a tunable dye laser operating at 0.463 and 0.466 μm. This method of remote sensing of pollutants has been shown to be more sensitive for gaseous pollution monitoring than Raman or resonance Raman scattering and fluorescence.

A dye laser is continuously tunable, hence an absorption line can be probed by tuning the laser to line center. While this is very convenient in the visible and near uv region of the spectrum, dye lasers are not available in the ir region beyond about 1 μm. Parametric oscillators are continuously tunable in that region, but are limited in power. Walther's group is using CO_2, CO, and DF lasers which have many fixed ir frequencies. The use of such lasers in multiline operation allows several pollutants to be measured simultaneously. However, since the lasers are not tunable, one has to find near coincidences between laser lines and pollutant absorption lines. Fortunately several coincidences exist in the following wavelength ranges: 2.8-3.0 μm (DF), 5.2-5.5 μm (CO), and 9.6-10.6 μm (CO_2). All of these lasers have spectral ranges that coincide with good atmospheric windows. However, radiation from the HF laser is strongly absorbed by atmospheric water vapor, therefore only short range measurements are possible with an HF source.

Walther's group has constructed a lidar having a transverse-excited-atmospheric (TEA) laser source which operates with the gases mentioned at pulse energies of 1000 mJ (single line) with CO_2 and 50-600 mJ (all lines) for CO, HF, and DF. A Ge:Hg 20-element array detector having a size of 0.1 × 2.0 mm is used in conjunction with a grating spectrograph. The receiver telescope has a 0.6-m diam., 0.24-m focal length, and 0.04-mrad field of view. With this system it is possible to measure up to 20 separate signals when the transmitter is running in multiline operation. When using CO_2, however, multiline operation does not work well with Walther's laser and the spectrum must then be tuned one line at a time.

Since the laser coincidences are not exact, one must correct for errors introduced as a result of the absorption coefficient varying as the absorption line breadth changes due to pressure broadening. The way in which the absorption coefficient varies with pressure or concentration depends on the frequency separation between the laser line and the absorption line center as well as the relative sizes of self- and foreign-broadening coefficients. The group has carried out theoretical and experimental investigations to determine this effect for various gases and pressure regimes.

The IAU is under the direction of Dr. Reinhold Reiter. He was away in the US during my visit, so his assistant Dr. W. Carnuth escorted me around the laboratory. The IAU has been a laboratory of the Fraunhofer Society since 1962, but its basis was the work of Reiter in München in 1950.

In addition to their central laboratory in the outskirts of Garmish (which is 740 m above sea level) the Institute has two mountain-top observatories at Wank Peak (1780 m) and Zugspitz (2964 m). Both are heavily instrumented to make measurements of atmospheric radioactivity, electricity, and meteorological data and to do aerosol physics and chemistry. In addition the cable cars going to both peaks measure meteorological data, while rawinsonde releases are made periodically. The Institute is in communication with all the remote sites, cable cars, and rawinsonde by radio.

The development of lidar has permitted the Institute to expand its investigation of atmospheric aerosols. They are now able to make measurements remotely up to at least 20 to 30 km and sometimes higher. They have developed two multi-wavelength lidar systems, one being stationary, the other a mobile unit. The stationary system has been calibrated to measure aerosol concentrations.

It is very difficult to calibrate a lidar in terms of aerosol concentration because the backscatter depends on particle sizes, shapes, indices of refraction, and size distribution. Certain simplifying assumptions have to be made concerning the shape and index of refraction of the particles. When the particles are assumed to be perfect homogeneous spheres of known index of refraction, Mie scattering calculations can be performed for volumes containing known size distributions. The IAU has a tremendous advantage as they have continuous measurements of aerosol concentration and size distribution from three altitudes and, in addition, vertical profiles of Aitken nuclei concentrations between 700 m and 3000 m from cable-car instrumentation.

The DFVLR has been active in lidar measurements for several years and in a space lidar program. The specifications of that space system were described by Rostron recently (see *ESN* 33-1:31) and will not be described here. The atmospheric work is carried out by two groups and is concerned with four areas: Airborne testing of a lidar system for Space Lab, optical measurements for a NATO-project "OPAQUE" (Optical Atmospheric Quantities in Europe), laser-target interaction studies, and a program for determining atmospheric parameters by remote sensing.

As part of the Spacelab Lidar Simulation Program Ch. Werner and his associate F. Köpp participated in tests conducted by NASA and ESA, the European Space Agency. Flight tests were made for ten days in the US in 1977 of a lidar employing a Nd-glass laser installed in the NASA CV 990 aircraft. Afterward Werner felt that in many respects a spacelab-borne lidar experiment would be inferior to and perhaps 10-times more costly than an airborne lidar system when used for tropospheric measurements.

The OPAQUE project was devised for the purpose of establishing the ability to describe the climatology of Europe based on optical measurements, and several heavily-instrumented sites are in operation in European countries. The DFVLR's part in this program is to conduct daily flights for one week out of every month over OPAQUE sites in Germany and the Netherlands. One portion of the optical equipment is a photometer system consisting of 6 photometers to measure sky and earth radiance operating at wavelengths of 400, 550 and 900 μm. Four of the photometers are periodically deflected over 15° increments. Two pyranometers, one looking upward and the other downward and each having a field of view of 160°, make total energy measurements. Also a backscatter sonde, consisting of a xenon flash lamp and optical receiver, points upwards. It measures backscatter from aerosols and molecules from a scattering volume extending from about 0.2 m to 10 m from the instrument. The processed data, when aided by visibility measurements at the ground stations, are used to calculate the slant meteorological visibility as a function of altitude in addition to the horizontal variation of the directly measured quantities.

W. Renger, who is a member of the NASA-ESA Space-Lab lidar Consultant Group, is working on an aircraft-borne lidar for environmental measurements in the atmosphere, looking down. He plans to use a Nd-YAG laser at 1.06 μm and its frequency-doubled output at 0.53 μm. In addition future plans call for a tunable laser to make concentration measurements of SO_2 as a function of height and horizontal position using the differential absorption lidar (DIAL).

The use of lidar for environmental measurements is based on backscattering from tropospheric aerosols. The interpretation of such measurements is difficult because of the way in which backscatter intensity varies with particle size in the Mie region. Particle size distributions vary depending on their origin, and sizes are humidity dependent. Werner along with Köpp and G.S. Kent have recently investigated the effect of using a two-wavelength system (a ruby laser at 0.6943 μm and a Nd:glass laser at 1.06 μm). They calculated the backscatter ratio, using Mie theory, for four aerosol models: Maritime, maritime plus desert dust, pollution, and con-

tinental clean. The models were derived from the literature and fitted to bimodal log-normal distributions with one peak lying in the so-called "coarse particle mode" (2.5 to 25-μm particle radius) and the other peak in the "accumulation mode" (0.05 to 0.5-μm particle radius). The calculated ratio varies with mean radius and is different for all models. For any one model the ratio also varies with humidity since that affects the mean radius.

They have made several measurements from the ground and determined the two-wavelength backscatter ratio as a function of height. An eight-channel solar radiometer simultaneously measured the atmospheric transmittance from which the aerosol optical depth could be determined at these eight wavelengths. The results indicate that two-wavelength lidar measurements can be useful for identifying tropospheric aerosols. In addition the airborne measurements are useful for studying aerosol transport mechanisms.

In addition to their other lidar instruments, the DFVLR has developed a mobile ruby lidar system with scanning capabilities. The basic reason for developing this system was to make measurements of smokestack emissions from ranges up to 5 km.

Remote sensing with lidar is becoming an activity of greater interest in several places in Europe. These three groups have developed innovative instrumentation and have produced considerable amounts of useful data over the past few years. (Vern N. Smiley)

MATERIAL SCIENCES

A METALLURGICAL DELAEY AT KATHOLIEKE UNIVERSITEIT LEUVEN

Professor Luc Delaey was my host on a recent visit to the Departement Metaalkunde of Katholieke Universiteit Leuven. Actually, Delaey is an old friend and postdoctoral co-worker of ten years past at Mellon Institute, and it is always interesting to observe the professional progress of someone who has shared a similar background with oneself, i.e., who has made some of the same "stops along the way." The energy Delaey has expended in Leuven over the last ten years seems to have had a strong effect on the research flavor in the Department Metaalkunde, where a major area of study concerns nonferrous alloys particularly of the type that display martensitic transformations and related "shape-memory effects" (SME).

At the time of my visit in early October 1978, Delaey had just returned from the States where he had attended the "First General Conference on Nitinol Heat Engines" held 26-27 September 1978 at the Naval Surface Weapons Center (NSWC), White Oak, Silver Spring, MD. In fact the heat engine developed at Leuven is based on Cu-Zn-Al alloys, not NiTi "Nitinols." The engineering development of the Cu-Zn-Al heat engine at Leuven is a dramatic example of the output of years of activity in the area of copper-based martensitic alloys. This applied work is in addition to extensive fundamental studies on phase transformations in this kind of alloy, reflecting another aspect of research at Leuven, namely that there is typically a well-balanced mixture of basic and applied metallurgy.

The Departement Metallkunde is divided into three sections that work closely with each other in research: Physical Metallurgy and Metallography (Profs. L. Delaey and A. Deruyttere), Mechanical Metallurgy and Nuclear Energy (Profs. Etienne Aernoudt and P. DeMeester), and Chemical and Extractive Metallurgy (Profs. Jef Roos and M. Brabers). This Metallurgy Department would be a rare breed in the US as here is no research on polymers or ceramics and, in fact only very limited teaching of the popularized topic we call "Materials Science." They have no ambition whatever to become a Department of Materials Science nor to expand the permanent staff in any way and these both seem wise conservative choices. The six full-professor faculty comprises an energetic and expert group that carry out what seem to be ingeniously interrelated research activities. There doesn't seem to be the typically American ambition to expand the staff into all the far corners of the materials arena.

The research emphasis is almost exclusively on nonferrous alloys. The typical tendency of US metallurgy departments to follow technological trends and, therefore, to emphasize research

on high-market-volume materials, is not seen here. In fact the reverse situation exists, in that the activities of the Department are intended to influence Belgian industrial technology by means of new metallurgical breakthroughs. For example, research with an applied metallurgical tone is being done in the areas of martensitic alloys, powder metallurgy, chemical metallurgy, and other areas; this work has close connections with Belgian industrial technology either through direct university industry cooperation or through government-industry research funding arrangements.

Although the Department is at first glance a small one, it is, in fact, the largest metallurgcal research group at a Belgian university, with approximately 45 research staff members, including permanent, postdoctoral and predoctoral workers. It seems to be very comfortably funded and has plenty of clean and well-organized laboratory space, fine equipment, generous technical support, and student interest. In short, a very healthy situation.

Research support comes from a number of sources, including general university funds for research (Fonds Derde Cyclus), and direct support by various agencies such as NFWO (National Fonds Voor Wetenschappelijk Onderzoek), Krediet aan Novorsers (essentially the Belgian NSF), and the government-industry agency IWONEL (Instituut voor Wetenschappelijk Onderzoek in Nijverheild en Landbouw). The Department is also in the second year of a special five year government "concentrated-action-grant" (Gekoncerteerde Akties van de Dieust Programmatie Wetenschapsbeleid), which orginated in support of the CuZnAl work and is currently the major source of Department funds. This explains why so many faculty and research staff members are presently co-working in this general family of materials. The Department also receives direct support from industry, usually on more applied matters (for example, a good deal of failure analysis support is provided).

The five year concentrated-action-grant has been used to acquire many major pieces of research equipment that will be of long-term and general use. For example, funds have recently been obtained to purchase both a new SEM (scanning electron microscope) and a TEM (transmission electron microscope), to augment the two-of-each already on hand. There are also excellent facilites for mechanical testing, fabrication, and powder metallurgy, the latter including equipment for powder characterization and a new atomization setup under construction.

In a department faculty as well-integrated as the one at Leuven it is often difficult to delineate the separate research contributions of the different faculty members. Each professor has his own areas of special interest, but there are numerous cooperative efforts and the faculty tend to work in complementary areas. For example, the activities of the "Delaey" CuZnAl group are quite extensive and involve at least four professors (Delaey, Deruyttere, Aernoudt, and Roos). The specifics of the research are too extensive to describe in detail. Regarding the shape memory effect behavior of these alloys, which is the central interest, both basic and applied research is being vigorously conducted. Historically, Delaey and co-workers have developed extensive information on the structural and microstructural features of phase transformations in beta phase BCC (body-centered cubic) noble-metal-based alloys. Such studies, rather than diminishing in favor of other types of work, have simply been augmented by the group's more recent work on various related aspects of these alloys. For example, the thermodynamics of stress-induced martensitic transformation has recently been the subject of rigorous analysis by Roos and Patrick Wollants; this work has special significance with respect to the application of the aforementioned SME heat engines. Also, the engineering properties of CuZnAl alloys have been studied, including damping, corrosion (Roos and J.P. Celis), and fatigue (Deruyttere). The damping work was partially supported by the US-based organization INCRA (International Copper Research Association), who have an interest in the possible application of numerous copper-base alloys (including CuZnAl) in noise and vibration reducing roles.

Very significant advances in the melting, casting, and fabrication of the Cu-Zn-Al alloys have been made (Aernoudt and Deruyttere). There are facilities for vacuum induction melting (approximately 8-kg heats; and heats up to 1000 kg have been made in industry), for hot extension of rods, tubes and sheets, and for wire drawing. The floors and racks are littered with evidence

of the remarkable success in fabricating Cu-Zn-Al alloys, and it is much easier to form these than the classical NiTi SME alloys. Cold working the alloys is difficult, however, while hot working must be carefully controlled to avoid excessive grain growth and dezincification of thin sheet products. In fact this Department with its facilities and staff must represent one of the world's most capable fabricators of brass-type SME material, an expertise that may eventually pay large dividends if these materials begin to realize their application potential.

Aernoudt and his group have found that powder metallurgy Cu-Zn-Al alloys have increased strength compared to conventional cast and hot-worked material, owing to fine grain size, dispersion and texture strengthening effects. The magnitude of the transformation strain is similar, but fatigue life is better, and because of the higher strength, higher reversion stresses can be executed by the shape-memory effect.

In addition to the wide range of activities connected with the CuZnAl alloy system, the Department has many other research interests in nonferrous metallurgy. The major activities of Aernoudt are in the area of deformation and texture development. Outstanding facilities have been developed for x-ray diffraction of pole figures via computer interfacing, and both theoretical and experimental determinations of deformation textures are carried out. For example, the Taylor theory of polycrystalline deformation (1938) has been generalized into a model for the calculation of deformation textures for processes with arbitrary material flow. These studies are intended to develop expertise in the prediction and analyses of cold-forming processes. Microstructure property relationships are also of interest to Aernoudt, as for example the relationship between strength anisotropy and substructure in drawn and extruded powder-metallurgy Cu-Al_2O_3. Currently, he and DeMeester are examining the features of unidirectionally solidified Cu-Cu_3Al.

Roos is involved in a variety of research activities that exceed the usual range of interest of the classical chemical/extractive metallurgist. His current research includes various studies in powder metallurgy, thermodynamics (of stress-induced martensitic transformation), metal refining (decopperizing of lead with sulfur and selective recovery of metals by ion exchange), and several other areas. Recently, Roos and J.P. Celis have emphasized the study of electrodeposition of composite coatings, especially the codeposition of Al_2O_3 particles in copper. Very fine particle sizes, as small as 0.05 μm, have been attained. The deposits are prepared from copper sulfate plating baths, with the Al_2O_3 particles kept in suspension by a pumping process. Using a sprayed electrolyte, they have developed a cell for continuous powder production. One of the interests in these composite deposits is their ability to retain as-plated hardness in high temperature conditions. It has been found in the Cu-Al_2O_3 system that the recovery temperature can be increased from 150°C to 450°C.

The research interests of Deruyttere, Head of the Department, are mainly in the area of strengthening mechanisms in alloys. For example, he has recently considered multicomponent solid solution strengthening and softening, using a theoretical model based on electronic structure and comparison with available experimental data. An extensive study of solid solution strengthening of tantalum is being made, with the aim of developing substitutional alloys with better mechanical properties than the pure metal at temperatures up to 300°C, while retaining the excellent room temperature corrosion resistance and deformability of the base metal. DeMeester, the current Dean of the Faculty of Engineering, is also active in the mechanical metallurgy area, especially as related to nuclear materials. Work on mechanisms of low-temperature plastic deformation in metals, such as vanadium, is underway. The mechanical metallurgy group also include activities in superplasticity, biomechanics and biomaterials. The last area touches once again on the CuZnAl alloys, whereas the SME effect is being employed in certain rehabilitative devices. The biomechanics area also includes some of the only nonmetallic research of the Department, regarding the mechanical properties of bone; this work is being done in association with the Division of Orthopedic Surgery.

Brabers' main interests are in environmental interactions, including the corrosion behavior of steels, biological implants, and compatibility studies (e.g., Ta with pure and doped $ThO_2Y_2O_3$).

It might be mentioned in concluding that there are actually two autonomous Catholic universities in Leuven. The one under discussion in this note, Katholieke Universiteit Leuven (KUL), dates from 1425 and is therefore the oldest Catholic university in the world. As is well known, the university was until 1968 divided into Flemish-speaking and French-speaking sections. However, in that year, a complete separation was carried out, in keeping with the social structure of Belgium, which is divided into a Flemish-speaking community in the north and a French-speaking community in the south. KUL is the largest university in Belgium, with about 18,000 students. The corresponding French-speaking university, known as Université de Catholique, Louvain has about 15,000 students. It also has a small metallurgy research group headed by Prof. A. Berghezan; the work here is mainly in alloy design, especially through the development of dispersed-phase materials such as Co-CoO and Co-WC, and through the development of high Mn, low-Cr stainless-steel type alloys. (Jeff Perkins)

MATERIALS FOR WIND AND WAVE POWER DEVICES

In the last few years, there has been a considerable increase in offshore facilities which are connected in some way to what may be broadly termed "energy technology." The most prominent example, of course, is off-shore oil drilling rigs, and in the UK a lot of interest has naturally been expressed about corrosion problems in the relatively new North Sea fields, and several recent scientific and technological meetings have considered the relevant materials problems (see for example *ESN* 30-4:165). Another branch of "new energy technology" that is much less developed involves schemes to convert the energy of wind and ocean waves to usable forms. Since the concept of wind energy conversion is considered to have the greatest potentiality at ocean sites (see *ESN* 31-8:302), both wind and wave energy conversion plants will involve similar environmental conditions for their materials of construction and operation.

The UK is considered to be quite favorably situated with respect to the availability of wave energy and a significant Department of Energy program has been in operation since 1976 to investigate the feasibility of extracting this energy. Several device concepts are being developed, and in some cases 1/10-scale prototypes have been constructed. Ultimately, full-scale wave-power devices may operate in areas as far away as west of the Outer Hebrides, where routine maintenance and inspection will be very limited by the harsh environment. Moreover, the nature of operation of some of the proposed devices will be outside current experience even in a more benign marine environment. Therefore, materials requirements for the devices will generally be more stringent than for conventional marine applications.

Also, consideration is being given at present to the possibility of siting large windmills (> 1 MW) in shallow (20 m) offshore UK waters in gigawatt arrays. As noted by one delegate to the meeting reported here, "Who better than the government to recognize the value of wind?" With design lives of 20 years or more, careful assessment of candidate materials is required, particularly with respect to stress corrosion and corrosion fatigue behavior in the marine environment. In an attempt to evaluate the state of readiness of UK materials science and technology for these new applications, the Materials and Testing Group of the Institute of Physics (!) sponsored a one-day meeting on the topic noted above in the title, at the Imperial College of Science and Technology in London on 19 December 1978. The program consisted of 11 papers, keynoted by Prof. A.A. Wells (The Welding Institute, Abingdon, UK). There were 56 registrants.

Wells, developer of the "Wells Oscillator" wave power device that has actually been tested at sea, started the proceedings with a review of some of the important considerations for offshore deployments in general, from ships to oil rigs to submarine pipelines. He started his presentation with a review of the physics of ocean waves. Any sailor knows very well that wind produces ocean waves, but according to Wells there is no general agreement on the mechanism of energy transfer from the wind to the water. He stated that

the formation of open ocean wave patterns is due to slip between the air, moving at a higher velocity, and the sea. He also used an interesting analogy as part of his illustrative data, namely the familiar interfacial wave patterns formed in explosive welds, where the metal at the colliding (and slipping) interface momentarily behaves like a liquid, then is frozen in place.

Offshore structures must certainly be one of the most difficult applications in all of steel design. This arises mainly because of the wide range and unpredictibility of forces to which they are subject. The ocean wave spectrum, for example, is broad band, so that appropriate corrosion-fatigue testing programs are difficult to delineate. There are also the occasional high forces owing to squalls and storms to contend with, the possibility of resonances that may accentuate fatigue loading, etc. In fact, the catalog of miseries that these structures must endure is quite appalling; there are numerous sites where stress concentrations, welded joints, surface flaws and other defects may crop up, not to mention almost unavoidable general corrosion and/or environmentally-assisted (corrosion) cracking problems. Although there is a good deal of value in the experience gained to date with oil drilling rigs, these are essentially static ocean-sited structures, whereas wave energy conversion plants may or may not be static; windmills at sea probably would be static structures. There is a significant difference between ships and other floating bodies and stationary ocean structures; the last must in effect "take it on the chin" when absorbing environmentally-transferred service loads. Wells brought up an interesting suggestion regarding the basic philosophy of designing offshore structures. Referring to the famous "aeroelastic" design of the Boeing 707 aircraft (anyone who has ever taken off in this plane knows the feeling that the wings are flapping like those of a goony bird), he indicated that there may be a future for analogous "hydroelastic" designs rather than the rigid offshore structures currently being used.

In addition to Wells' introductory talk, two other presentations reviewed more specific applications areas. J.A. Hudson, Atomic Energy Research Establishment, (AERE), Harwell, UK and P.J. Worthington (Central Electricity Research Laboratory, Leatherhead, UK) considered materials aspects of wave-power devices and sea-based windmills, respectively. Hudson indicated generic areas of materials in which current knowledge forms an adequate base for development of wave power devices. He stated that the large amount of experience with conventional marine applications as well as recent experience with oil and gas platforms in the North Sea is of great value. He also mentioned specific aspects of early device designs in which materials problems may arise. In particular, corrosion, corrosion fatigue, and the effects of marine fouling must be considered with respect to both the main structure and other components such as the mooring and power take-off systems. The effect and mechanism of stray current corrosion due to ac cables is being studied at AERE. Also, the behavior of wire ropes and ropes of man-made fibres is underway at AERE and other UK labs. Marine fouling, the accumulation of masses of marine biological matter on surfaces, may be a critical consideration; this is a phenomenon that, by enlarging the legs of oil rigs, has been known to effectively convert them to wave power devices, so who knows what this might do to the performance of a device intended as a wave energy converter?

Worthington considered how the marine environment might affect the choice of material for the long-term performance of windmill structures, with particular attention to the rotor and blading materials, in view of the high loadings these components will experience. The scale of these windmills is a tower extending approximately 50 m above the water surface, with blades extending 30 m from the rotor hub. Such a structure must carry several blades weighing 10 tons each if made in steel, 5 tons if GRP. There is very uneven (space distribution) loading of many components as well as unsteady (time distribution) loading patterns. The catalog of corrosion modes that are anticipated is very extensive, although little real data are available yet.

Turning to papers on specific materials problems for metals, the main interest is in environmental cracking modes that will plague the major structural and load-bearing components: corrosion fatigue (CF), stress-corrosion cracking (SCC), and hydrogen-assisted

cracking (HAC) were considered by several authors at the meeting. P.M. Scott (Harwell Corrosion Service, Harwell, UK) summarized results from CF crack growth tests on structural steels carried out as part of the UK Offshore Steel Research Programme, and current views on the mechanisms involved were described. This program is apparently in what must be considered a preliminary phase, since the tests were conducted at constant amplitude and frequency (10 sec/cycle), and therefore don't offer much insight to the much more demanding situation of randomized wave loading. However, Scott's data, in the form of crack growth "rate" vs stress intensity factor range, i.e., da/dN vs ΔK, is of interest in terms of the effect of potential and painting on crack growth behavior. In tests that span the potential range from underprotection to overprotection there is approximately a factor of 6 scatter in da/dN. The interesting thing is that cracks grow even at (macroscopic) potentials where dissolution supposedly cannot occur, suggesting the possibility of hydrogen (a cathodic product) assisted cracking (HAC). Also, painting does not stop cracking, although it slows it down. Scott's da/dN data show the very interesting result that a crack in a painted specimen takes longer to get started, leading to a factor of around 4 greater life in their specimens, however, once the crack gets going it actually travels at the same rate as in the unpainted specimen. Scott's interpretation of this behavior is in terms of the amount of hydrogen accumulated in the volume of the specimen as a whole, which is consistent with the idea of a longer rate of accumulation in painted specimens. This hypothesis suggests that the equilibrium amount of hydrogen in the specimen bulk has some relation to the (local) cracking process. This idea would seem to be based on circumstantial evidence at present.

B.S. Hockenhall (Cranfield Institute of Technology, Bedford, UK) also discussed research on corrosion fatigue of steels in seawater. His particular interest was how to handle the well-known frequency effect in corrosion fatigue, which among other things makes it difficult to speed up tests by exceeding the real-life frequency. Frequencies of interest are less than 1 Hz, so that very long experimental times are required; for the loads involved, the crack growth rate is on the order of 10^{-6} to 10^{-8} m/cycle. It is worth noting that the familar "rate" used in the "Paris" plots of da/dN vs ΔK is not a rate at all unless the frequency is quoted. Hockenhull's data show that da/dN (increment of crack extension per cycle) is lower for higher frequency but that da/dt (increment of extension per unit time) is higher. Most of this work was at 0.1 Hz, extending up to 10 Hz. Hockenhull's group used both crack-opening displacement (COD) and ac-resistance methods to measure crack growth rates. An interesting twist is the use of a pulsed ac system to avoid, as much as possible influences of the measuring system on the natural electrochemical processes; also, the test is calculated to consider the effect of the state of opening of the crack at the instant of measurement. One of the most interesting revelations stated by Hockenhull was that of a frequency effect on fatigue in air. This has historically been discounted due, according to Hockenhull, to the use of too narrow frequency ranges. In studies over the range 0.1 Hz to 10 Hz, a weak frequency effect can be distinguished in air.

T.J. Baker (Imperial College of Science and Technology, Univ. of London, UK) discussed recent work on HAC, a perennial problem in oil rigs and other situations in the petrochemical industry. The deleterious effect of hydrogen on the mechanical properties of steel is well known, as pointed out in two reports by Bernstein (see *ESN* 32-3:99 and 32-11:375). In the past most attention has been given to high strength steels (yield strength above 1500 MN/m^2 or so) where hydrogen effects are seriously felt. In his paper, Baker showed that there is increasing evidence to suggest that hydrogen can lead to deterioration in properties of low strength steels (yield strength as low as 400 MN/m^2). In the research reported by Baker, the role of nonmetallic inclusions on HAC behavior is being studied for steels at various strength levels. Although the role of inclusions on the fracture behavior of steel in air has been extensively studied, little is known about their effects on HAC. In the recent past a number of failures of pipelines handling sour (containing H_2S) gas or

oil has been reported. In all it has been observed that the fracture process involves the active participation of inclusions. Preliminary quantitative work indicates that the critical inclusion-related parameters which determine susceptibility to HAC are inclusion-volume fraction and morphology, and specimen orientation. Therefore, in addition to matrix strength, these inclusion variables have been studied. The model system used in the study is a medium carbon hardenable steel (UK designation En 16) in resulphurized (0.15% S) and normal sulfur (0.05 S) versions. With this alloy system it is possible to obtain a uniform dispersion of MnS inclusions, and the matrix strength can be changed without affecting the inclusion distribution. Test environments used have included NaCl solution, H_2S gas, and H_2S-saturated acetic acid. Among the interesting observations are a stronger specimen-orientation-dependence at lower strength levels, and less orientation dependence at higher sulfur levels. Baker reviewed the possible mechanisms by which the sulfide inclusions cause these effects, including microscopic stress concentrations and effects on segregation and/or transport of hydrogen owing to the inclusions.

Other papers at the conference considered the behavior of other classes of materials in the marine environment. L.S. Norwood (AERE) discussed work on the long-term performance of glass-reinforced plastic (GRP) composites, and T. Hodgkeiss and coworkers (Univ. of Glasgow, UK) made some observations on the mechanism of fatigue of reinforced concrete in seawater. Norwood discussed factors influencing GRP laminate performance after long (25 yrs desired) periods of immersion in water. The two basic phenomena which have been studied are water absorption as a function of time and leaching, and the long-term data show the importance of not relying on short-term test results. The importance of choosing the correct gel-coat/resin/glass system was emphasized. Also, the effects of fabrication defects on the performance of GRP in marine environments were considered. There is a limited amount of real-life experience available in this area also, with most of it coming from GRP boat hulls, a few of which have been in service since the mid-1950s. At Glasgow, Hodgekeiss's group is studying the fundamental mechanisms of fatigue of reinforced concrete in seawater. Among their observations is the fact that there is no significant effect of loading frequency in air over the range 0.17 Hz to 5 Hz and that fatigue life at 0.17 Hz is not reduced in seawater. Details of the failure modes were discussed.

Technologically, much of this wind and wave energy activity is clearly residual from the 1972-73 oil crisis, and as such might be considered as "insurance" technology. Whether or not these schemes are seriously promoted in the future in the UK is far from certain. In terms of the relevant materials science, the general connection between all marine materials applications is that the behavior of materials in these environments tends to be dominated by surface phenomena and therefore controlled by surface condition. Therefore, research on these kinds of phenomena is of value regardless of whether or not wind and wave power devices flourish in the future. (Jeff Perkins)

PULSED NUCLEAR MAGNETIC RESONANCE IN SOLIDS

Nuclear magnetic resonance (NMR) is a relatively recent spectroscopy, dating back only to 1946: indeed development of rf and radar electronics during the war years provided many of the first experimental techniques. Early work was done on both solid and liquid samples. Liquid state spectroscopy has evolved into a powerful yet routine method for chemical identification: the commercially available instruments are almost exclusively designed for liquids. Solid state studies continue to attract attention, but are by no means routine. A number of techniques (multiple pulse sequences, magic angle spinning, dipolar decoupling) have been developed that produce high resolution (liquid-like) spectra from solids. Others examine the nuclear quadrupolar coupling to determine the magnitude and sometimes orientation of the electrical field gradient owing to the valence electrons; in this way nuclear quadrupole resonance gives information about chemical composition.

In addition to spectroscopic information, NMR relaxation rates in solids can provide insight into the nature of the molecular motions felt by the observed nuclei.

To examine recent developments in solid NMR, the Faraday Division of the Chemical Society (UK) arranged a Symposium on "Pulsed Nuclear Magnetic Resonance in Solids." Fifteen papers were presented on 18-19 December 1978 at Queen Elizabeth College, London. Approximately 120 participants from 14 countries attended; most were from universities and industrial firms. The Symposium was conducted in the format typical of the Faraday Society. The papers had been preprinted and distributed to all participants well before the meeting. The speaker was allowed only 5 minutes to remind his audience of the central points in his paper, and then the audience addressed questions or comments to him for 20-40 minutes. A number of questioners had even prepared slides and overheads. This system allows a more equal interchange between speaker and audience, and so the caliber of the discussion was rather high compared to most conferences.

Prof. Erwin Hahn (Univ. of California, Berkeley) provided the introduction to the Symposium. He identified the scientific themes common to the 14 papers. Indeed, almost without exception, each paper was based on research and concepts he had pursued in the early 1960s.

Three papers employed multiple pulse line narrowing techniques to remove homonuclear dipolar broadening. Unfortunately, the author of the first paper, Dr. L.N. Erofeev (USSR Academy of Sciences, Chernogolovka) did not attend, and so there was no discussion of his paper. (One of his co-authors, B.N. Provotorov is a very highly regarded theorist in NMR.) A theme, identified by Prof. U. Haeberlen (Max-Planck-Institute, Heidelberg) and amplified by others, relates to the chemical shift tensor determined in crystalline materials by multiple pulse NMR: the crystal may impose an orientation to the chemical shift tensor of a molecule or even alter the principal values. Hence, the results of crystal studies may reflect more crystalline symmetries, rather than molecular ones.

Two papers examining the role of spin-spin processes in the determination of relaxation rates due to molecular motion in organic solids were given by Dr. E.O. Stejskal, (Monsanto, St. Louis, MO) and Dr. A.N. Garroway, (Naval Research Laboratory, Washington, DC). The general conclusion was that the interference of spin-spin processes could be minimized, although there was not agreement on precisely how to achieve this.

Hahn asked why the high resolution techniques using cross-polarization were more popular than the multiple pulse methods. (The two are complementary rather than competing techniques.) Dr. K.J. Packer (Univ. of East Anglia, Norwich, UK) said, with only a trace of hyberbole, that the multiple pulse techniques require the presence of an on-line physicist. It was agreed that these techniques are still very demanding even though they have improved markedly in their efficiency and ease of operation since their inception in 1966. It was also pointed out that a comparison based on popularity is not quite fair. Cross-polarization techniques have been combined with magic angle spinning; in concert they have been rather successful in analyzing reasonably complex molecules. Multiple pulse techniques are generally applied to proton or fluorine nuclei in simple molecules that may be in a crystalline phase. These studies are probably of less popular appeal simply because most chemists are attuned to ^{13}C spectra in rather complex molecules in the liquid phase.

A rather different high resolution technique, multiple quantum NMR, was presented by Mr. D. Weitekamp (a student of Prof. A. Pines, Univ. of California, Berkeley). So far this method has been limited to rather simple, magnetically isolated molecules.

Another series of papers indicated that quadrupolar resonance is becoming easier. Both Dr. D.T. Edmonds (Univ. of Oxford) and Prof. T.L. Brown (Univ. of Illinois) were optimistic that such techniques would become more accessible to other workers.

A final series of papers examined molecular motion in solids. Perhaps the most novel was presented by Prof. M.M. Pintar (Univ. of Waterloo, Canada). Pintar transfers nuclear polarization to the torsional ground state of a rotator (NH_4+ ion or CH_3). The low-temperature tunnelling splitting is directly inferred.

One cannot help but be impressed with the advances in solid state NMR

in recent years as revealed by this Symposium and the insight these techniques can give into the molecular and atomic organization of solids. Judging from the participants, both speakers and audience, the interest in solid state NMR is international, which may also reflect its scientific potential. (A.N. Garroway, Naval Research Laboratory, Washington, DC, and Willard D. Bascom)

INTERNATIONAL SYMPOSIUM ON QUANTITATIVE METALLOGRAPHY

The establishment of the relationship of microstructure-mechanical properties is probably the major concern of metallurgists today. In alloy-development research this "structure-properties" theme is being pursued from both sides: accurate measurements of average or local mechanical properties are being correlated with ever-more detailed determinations of microstructural features. The geometry of microstructures can now be rigorously defined in terms of certain parameters whose measurement comprise the field of analysis called quantitative metallography (QM), which in the last ten years has become a very sophisticated, automatic-instrument-dominated field. An International Symposium on QM was held 21-23 November 1978 in Florence, Italy, organized by the Associazione Italiana di Metallurgia under the auspices of the European Economic Community (EEC). The meeting was intended to promote discussion on the use of QM in general and automatic image analysis (AIA) in particular, with special reference to industrial laboratory application of these techniques, as for example in quality control and R&D. The meeting was attended by about 120 delegates (about 75 from Italy) who heard about 35 papers.

One of the highlights was a special session devoted to reports on a European cooperative program in QM under the auspices of the Community, with summaries given by five participating countries. This program had its origins in an initiative taken in 1972 in Turin at a meeting on Quantitative Methods of Image Analysis in Metallography. At Florence, the work of the participating groups was reported each in turn by H.P. Hougrady [Max-Planck-Institut für Eisenforschung (MPI, Dusseldorf, FRG]; K. Bywater [British Steel Corporation (BSC), Sheffield, UK]; H. Mathy [Centre de Recherches Metallurgiques (CRM), Liége, Belgium]; C. Lafonde [Institute Recherche Siderurgie Francaise (IRSID), St. Germain en Laye, France]; and V. Faccenda [Centro Sperimentale Metallurgico (CSM), Rome, Italy]. The work at all these laboratories is dominated by an interest in high-strength low-alloy (HSLA) steels (defined as those with yield strength above 450 MPa), and before launching into a summary of the reports given by the various groups, it would be useful to provide some background on the alloys that are the object of such detailed study.

Much interest has been paid in recent years to the development of HSLA steels because of the remarkable combination of strength, toughness, ductility, and weldability that can be obtained in the as-hot-rolled condition. These properties make them attractive for various critical structural applications, including pipelines. Considerable research has been done in the general area of controlled processing and microstructure-mechanical-properties relationships in HSLA steels. For example, phenomena that occur during hot rolling have been studied extensively, with attempts to rationalize mechanical properties such as yield strength, ductile-to-brittle transition temperature (DBTT), strain-to-fracture, etc. However, the critical property is fracture toughness, and this has been much more difficult to rationalize on a microstructural basis. Therefore, many laboratories have been conducting ever-more-detailed quantitative metallographic studies of HSLA steel microstructures. What is known is that there is an important role for nonmetallic inclusions, particularly sulfides and oxides, on the fracture behavior of steels. Unfortunately, the role is usually that of villain, so that a lot of effort is spent trying to eliminate these phases from the microstructure. It is well established that in HSLA steels significantly improved toughness can be achieved by simply lowering the sulfur and oxygen contents to below about 0.1%. As a consequence, the cleanliness of high-quality commercial steel has increased since the 1950s from 180-250-ppm sulfur to less than 100-ppm sulfur, and from more than 100-ppm oxygen to less than 20-ppm oxygen (in special cases, the

levels may be less than 10-ppm sulfur and 10-ppm oxygen). However, this approach has its limits, and the real need from both the practical and fundamental standpoints is for quantitative microstructure-properties models of the effect of particles of these nonmetallic phases.

Before going on to the conference papers on HSLA steel microstructures, a few general words on the qualitative aspects of alloy microstructural design and some very brief comments on classical quantitative metallographic methods: One of the key axioms of alloy design for higher strength is that finely dispersed microstructures (small grains and second phase particles) give higher strength and (usually) lower ductility. Also, relative to fracture toughness, it is well known that inherently brittle phases lead to lower fracture toughness, particularly when present as large or continuous morphologies, such as long thin particles or as grain boundary layers. From the standpoint of microstructural parameters in HSLA steels, the primary features of interest are grain size and inclusion content, so that these are the ones to which most QM efforts are devoted.

In metallurgical systems with a second phase, whether it is metallic or nonmetallic, one of the simplest QM assessments that may be pursued is the volume fraction of that phase. Classically this is done by relatively tedious measurements of point fraction by point counting over a given microstructural area, or from line fraction by so-called linear analysis. AIA, on the other hand, utilizes a direct measure of area fraction (numerically $V_f = A_f$) and when coupled to high magnification microscopes, can scan large areas to search for small particles. For AIA, the measurement of grain size and inclusion content present quite different demands in terms of machine operation and sample preparation. For example, etching quality and consistency is much more important for grain size determinations, for which uniform grain boundary etching is required, than for inclusion determinations. However, inclusion determinations actually have more serious problems, and the complexity of the problem can be appreciated just by considering the microstructural factors that affect strength. These include the shape, size, mechanical and chemical properties of the inclusions and their distribution and orientation with reference to the applied stress; also, the mechanical properties of the matrix metal and modification of these in the vicinity of the inclusions; and the nature and magnitude of the applied stress together with any residual stress. The problem is also illustrated by the fact that there are no fundamental laws to describe the relation of microstructural features such as those numerated above to the mechanical properties. In fact, this is one of the prime goals of much current research, and with this brief background, we proceed to a review of some of the key developments reported at Florence.

Hougardy described the QM system at MPI-Dusseldorf which may serve as an example of the level of sophistication that can be achieved in this field. The system accepts signals from optical electron microscopes or film projectors as inputs to a television measuring system, with all the devices controlled by a computer that also collects the data. The image itself can be stored for subsequent software analysis. Relative to their extensive application of this system to HSLA steels, reliability checks have shown that for accurate measurements high contrast is needed, which has been accomplished with interference layers. Specific applications have included the measurement of the dissolution of carbides in austenite.

The main concern of Bywater (BSC) was with comparability of the use of different machines in different laboratories. Using data from 7 different machines (including 4 Quantimet 360s and 3 Quantimet 720s), Bywater catalogued the effects of microstructural geometries, operator experience, sample preparation, etc. He emphasized the utility of calibrating machines against manually obtained values for a given lab situation, which seems ironic, but which apparently is essential at this point. Among the inter-group trails was a series of measurements on standard ferrite-pearlite specimens.

Mathy (CRM) also discussed the use of special sample preparation techniques [interference layers and special etching conditions for scanning electron microscope (SEM)] to improve results, and considered specific applications such as anisotropic structures and inclusions with various shapes. In QM

it is more difficult to measure certain morphological parameters if the feature is very irregular. In this case parameters such as area and perimeter do not obey the invariance conditions for symmetry as do more regular features, and special methods must be introduced to evaluate the structures.

The presentation by Faccenda (CSM) emphasized the use of transmission electron microscopy (TEM) and SEM methods, including transmission SEM and microfractography, to determine inclusion contents in high-strength low-carbon acicular (quenched and tempered) steels with sulfur contents ranging from about 200 to 20 ppm. In these materials the inclusion particle density is on the order of $10^7/mm^3$. Acicular steels, which comprise most HSLA types, are more susceptible to toughness-robbing by nonmetallic inclusions than those with lower-strength ferrite-pearlite microstructures. The crux of the CSM work is to sort out the role of small (<1 μm) inclusions in the ductile fracture (micro-void formation) process. The parameter that is measured in this connection is the total inclusion projected length per unit area (P_L), which has been shown by others to have good correlation with ductility; however, this applies to inclusions detectable by optical microscopy, which does not include the population with sizes <1 μm. The CSM work, using extraction replica TEM, has shown that even when the S content is reduced to around 20 ppm, the density of inclusions <1 μm is still on the order of $10^7/mm^3$. Thus, whereas their contribution to P_L is negligible at the higher inclusion volume fraction, it is of the same magnitude at the lower ones. Their conclusion is that a higher improvement in ductility of "clean" steels can be expected if the number of small inclusions is reduced. Voids have been observed around inclusions as small as 0.1 μm. CSM research also points up the importance of specimen preparation in QM/AIA. In some of the microstructures they have studied it is difficult to distinguish martensite islands from acicular ferrite, since both have very small dimensions, similar shape and contrast. The use of a combination of TEM and transmission SEM on the same thin foil samples (for calibration) and SEM on polished and etched samples has allowed unambiguous determinations to be made.

In addition to these reports, several other contributions were offered having to do with QM studies of steel microstructures. Another example of the application of QM to a classical problem in ferrous metallurgy was reviewed by S. Ekelund and coworkers (Swedish Institute for Metals Research, Stockholm), involving another class of steels, tool steels. In their research, they have made an effort to quantify the degree of carbide banding in high speed steels. Typically in these steels the apparent distribution of carbides within the matrix may be nonuniform, a combined result of the solidification microstructure and subsequent hot working. A simplified explanation of this is as follows: precipitation of initial carbides takes place mostly in the as-cast interdendritic regions, which creates local networks of carbides in the steel; hot working breaks these down to some extent but may, as a function of bar size and percentage reduction, introduce directional effects, referred to as carbide banding. The conventional way to assess this relies on the subjective judgement of a trained metallographer, often on the basis of comparison charts and with adherence to company or national standards. The work of the Swedish group is intended to develop an automatic, consistent and quantitative measure of carbide banding.

The application of AIA in industrial metallurgical quality control was considered in a separate vigorous session, keynoted by Prof. S. Johansson (Sandvik AB, Sandviken, Sweden). Again, ferrous metallurgical applications were emphasized. With its potential for drastically reduced time for analysis and the possibility of greater accuracy and inter-laboratory calibration, AIA is of great interest to quality control metallurgists. Since the main difference between classical QM methods, such as point counting or lineal analysis, and AIA is speed, it is possible to examine more specimens, scan larger areas, and measure more parameters in a given amount of time. However, in order to apply AIA correctly in quality control, care must be taken that the sampling procedure is correct, i.e., that the specimens examined accurately represent the bulk material. Also, variations in data (for example, inclusion size distribution) from sources other than

the true microstructural features must be accounted for. Specimen preparation, sample orientation, and tuning of the AIA are all of critical importance. Informed application of statistical methods to the data also has great value in checking the validity. Examples of the utility and difficulties of applying QM in industrial quality control were reported by various authors, including E. DiFrancesco and D. Pecchini (TEKSID SpA, Torino, Italy), P. Filippi (Breda Siderurgica, Milano, Italy), and J. Chone (IRSID Metz, France). While the power of QM is very evident, there are certainly some difficulties and doubts about the use of such techniques in routine quality control. H. Nordberg (Uddeholms AB, Hagfors, Sweden) considered some of the practical difficulties inherent in achieving quality control QM with AIA, using as an example the detection of large fatigue-strength-reducing inclusions in steels. One problem is that since there may be very few of the critical sized (>20 μm) particles per unit volume, the time required to search a sample for one may be very great, on the order of 50-100 hours with current AIA systems. Therefore, the value of statistical and mathematical analysis to the data was pointed out. For example, if the usual distribution functions for inclusion sizes are known, one may only have to collect data in a limited size range in order to reveal the entire distribution.

The conference demonstrated the sophistication of QM/AIA techniques in contemporary industrial laboratories for both research and quality control. These techniques are proving to be extremely useful in solving alloy development problems and will certainly become an essential part of quality control systems in the future. Some of the key problems in QM/AIA at present involve sampling techniques, specimen preparation, accuracy and reproducibility of AIA instrument operation, measurement of features with complex shape and/or small size, and the statistical principles of data analysis. It was satisfying to see that the papers presented at this meeting seemed to avoid one of the classical traps of microscopy, i.e., analysis for analysis' sake. The meeting appropriately included sessions on sterology principles and specimen preparation, but for the most part the importance of measuring a given parameter was put in the context of the importance of that parameter to the understanding of material properties. (Jeff Perkins)

MEDICINE & PHARMACOLOGY

THE KRYPTON (^{81m}Kr) PULMONARY VENTILATION SCAN AND THE RUBIDIUM (^{81}Rb) GENERATOR

The static chest radiograph is not adequate for the evaluation of pulmonary ventilation, although radiologists continue the struggle to diagnose airways disease based on it. Radiographic ventilation abnormalities can be detected only in rather advanced cases and even then with some difficulty as the radiograph represents the morphologic appearance of the chest in just a single fraction of a second. The advent of radioisotopic scans (blood perfusion) in 1963 was a giant step in the visual evaluation of pulmonary function. Several years later ventilation scans were developed using an isotope of xenon (^{133}Xe) for evaluation of a single breath or time of "washout." The next logical step was the development of simultaneous perfusion and ventilation scans in order to evaluate both overall pulmonary function and localized disease.

Pulmonary embolic disease, which is a major medical problem both in itself and as a complication of other disease states, is, of course, a natural target for evaluation by perfusion scans. However, if the lung is otherwise abnormal and blood flow is not uniform, then the perfusion scan alone cannot be used to detect pulmonary embolic disease. The common problem is a suspected pulmonary embolism in a patient with chronic obstructive airways disease, such as emphysema, in whom some distortion of pulmonary blood flow is expected. The simultaneous use of perfusion and ventilation scans has helped somewhat with the analysis of pulmonary embolic disease. However, ventilation scans have hitherto been hampered by several adverse properties of the commonly used isotope, ^{133}Xe. The single-breath xenon ventilation scan requires deep inspiration and breath-holding maneuvers that are not physiologic and are particularly difficult to obtain in patients who often are short of breath anyway. In addition, xenon images are not of good

quality, owing to the low counting statistics that are available during breath holding. The washout of ^{133}Xe is useful in detecting local areas of reduced or absent ventilation but does not provide a functional image. True functional images can be obtained with ^{133}Xe only if a computer is available. But such complicated procedures require considerable technical expertise, the expense of a computer, and a relatively long measurement time. The low gamma ray energy (80 keV) of ^{133}Xe not only makes it sub-optimal for imaging but a direct comparison with lung perfusion scans made at the same time with the higher energy ^{99m}Tc-HAM (140 keV) cannot be achieved.

Drs. Ferrucio Fazio, J. Peter Lavender, and Robert E. Steiner (Hammersmith Hospital, London) have rather extensively evaluated an isotope of krypton, ^{81m}Kr, relatively new to lung ventilation scans. The technique was described by Fazio and Jones in 1975. ^{81m}Kr has two very distinct advantages: A very short half-life of 13 sec and a high gamma energy of 190 keV. Naturally, the use of an isotope with a very short half-life requires the presence of its parent, in this case rubidium (^{81}Rb), which has a half-life of 4.6 hours and is gathered from a nearby cyclotron. An ^{81}Rb-^{81m}Kr generator has been constructed, which "manufactures" ^{81m}Kr on a continuous basis. It is not mandatory for the laboratory to be immediately adjacent to the cyclotron. ^{81}Rb is actually distributed to many centers in Europe from the London cyclotron and can be used in a similar way by workers at some distance. The half-life of the parent rubidium allows the krypton to be available continuously throughout the day for ventilation measurements after a morning's production of the rubidium. If ^{81m}Kr is added to inspired air during normal breathing, equilibrium of the isotope with the gas in the alveolar spaces is never reached because of the very short half-life. Because of this property a ventilation scan made with ^{81m}Kr is truly representative of ventilation, rather than pulmonary volume, which makes it quite different from ^{133}Xe and ^{85}Kr, both of which are now in common use for "ventilation" scans.

^{81m}Kr then becomes a natural isotope for use with the ^{99m}Tc perfusion scan in a combined procedure. A patient is given a single intravenous injection of ^{99m}Tc-HAM while he is sitting in front of a large-field gamma camera and breathing normally through an ordinary face mask. Three hundred thousand counts are collected from the injection of the ^{99m}Tc-HAM with the windows set for 140 keV and a perfusion picture recorded on film. Immediately after completion of the picture, a continuous flow of the ^{81m}Kr is added to the inspired air and the windows reset to 190 keV. A ventilation picture can then be made again, collecting 300,000 counts in approximately one minute. The "spillover" of ^{99m}Tc-HAM into the ^{81m}Kr window is minimal (less than 3%). Both scans, ventilation and perfusion, can be obtained in 2 to 4 minutes for each view, and the patient is actually unaware of the switching from the perfusion scan to the ventilation scan and unaware that ^{81m}Kr has been added to the inspired air.

The whole-body absorbed radiation dose from the ^{81m}Kr ventilation study, if four views are made, is less than five mrads. The dose to the lungs is approximately 40 mrads. The whole-body absorbed dose from the ^{99m}Tc-HAM perfusion study is less than 20 mrads and a lung dose 280 mrads.

Another mundane but important advantage of the ^{81m}Kr is the absence of a waste disposal problem, because of the extremely short half-life.

The Hammersmith Group has evaluated over 100 patients, 75 of whom were included in a report in the *American Journal of Roentgenology* in 1978. Patients were grouped into three categories: those with chronic obstructive airways disease, those with suspected pulmonary embolic disease, and those with chronic left heart failure. In all three groups, a comparison was made with standard chest radiographs. In the first group, those patients with emphysema and other airways obstructive disease, the chest radiographs correlated very poorly with the ventilation-perfusion scans and showed a trend to underestimate the functional impairment. As previously indicated, this is a well-known problem in the evaluation of chest radiographs, and radiologists are aware that usually emphysema can be seen only in its more advanced stages on the chest radiograph. In chronic bronchitis and asthma a similar deficiency of the chest radiograph was observed, as large segmental defects on both the ventilation and perfusion scans were associated with normal radio-

graphs. In the group with pulmonary embolism, once again the chest radiograph was normal unless a pulmonary infarction had occurred. The number of pulmonary emboli that do not cause infarction is many times greater than those that do. A number of segmental defects strongly suggestive of pulmonary emboli were seen on the perfusion scans with normal radiographs. As expected, a true ventilation scan made with ^{81m}Kr in these patients was normal as well. Although it is well known that there is a redistribution of pulmonary blood flow from the lower lobes to the upper lobes in chronic left heart failure, the Hammersmith group actually found that radiographs were relatively inaccurate in predicting this alteration if compared with the perfusion scan.

Dr. Lavender has indicated that since their 1978 report additional uses have been found for ^{81m}Kr. The differential diagnosis of pulmonary infarction and pneumonia is often a difficult one, particularly in elderly patients who have some degree of heart failure as well. The use of the ventilation-perfusion scan combination has been of considerable assistance in making this differentiation. Patients with pneumonia have a relatively normal perfusion scan but an abnormal ventilation scan, while those with pulmonary infarction will have a defect noted on their perfusion scan with relatively normal ventilation.

Dr. M. Silverman (Hammersmith Hospital) also has begun using ^{81m}Kr in an attempt to differentiate among the various pulmonary diseases of the newborn infant.

In summary, the use of ^{81m}Kr for ventilation scans, particularly with a virtually simultaneous ^{99m}Tc-HAM perfusion scan, is a significant advance in the visual evaluation of pulmonary function. In diseases such as chronic airways obstruction, pulmonary embolism, and chronic left heart failure, these functional scans provide greater information in many cases than do the static chest radiographs. Ventilation scans have been substantially improved by the use of ^{81m}Kr because of its very short half-life and high gamma energy. The rubidium generator is a simple and effective method of providing a virtually continuous supply of ^{81m}Kr. (Irwin Freundlich)

BRITISH PHARMACOLOGICAL SOCIETY, WINTER MEETING

The British Pharmacological Society's Winter Meeting was held on 3-5 January 1979 at Guy's Hospital Medical School, University of London. In spite of blistering winds, snows, and below freezing temperatures purported to be the worst in 100 years, it was exceptionally well attended. Perhaps the recognition by the Queen only the previous week of two pharmacologists [Prof. W.W. Paton of Oxford Univ. (Knight Bachelor) and Sir Walter Perry of the Open Univ. (Life Peer)] may have contributed to this phenomenal attendance.

The first day of the Meeting was devoted to 20 papers in clinical pharmacology, as well as to the Annual Lectures by the recipients of last year's Lilly and Gaddum Awards. The importance of diet, age, and interactions with other medications on the metabolism and bioavailability of drugs were the main points raised in this session. For instance, J.C. Mucklow and his associates (Royal Infirmary, Newcastle upon Tyne), using 32 subjects, found that the clearance of antipyrine is almost twice as fast in meat eaters as in lactovegetarians. Further analysis of the data showed that this difference was not due to the greater protein intake of the former group, but rather to the differences in consumption of animal fat. B. Fulton et al. (The University, Newcastle upon Tyne) reported that in the elderly (72-78 yr), not only were the rates of certain drug oxidations reduced but also conjugation reactions were inhibited. In contrast, an important cause of drug interactions and drug-induced disease in epileptic patients appears to be due to the fact that many commonly used antiepileptic drugs are potent inducers of hepatic microsomal enzymes. E. P Perucca, A. Hedges, K. Makki, and A. R Richens (Institute of Neurology and St. Bartholomew's Hospital, London) compared the most commonly used antiepileptics and found that antipyrine half-lives and excretion of D-glucaric acid in a large group of patients were considerably greater in those treated with phenytoin, primidone and carbamazepine, whereas sodium valproate did not appear to share these effects. The concept of taking into consideration all of these factors in arriving at an effective and safe

therapeutic dose was repeatedly emphasized throughout the meeting.

Another interesting study in humans was reported by researchers from the Royal Air Force Institute of Aviation Medicine, Farnborough, Hants., (A.N. Nicholson and Barbara M. Stone) investigating the usefulness of L-tryptophan in the management of sleep onset and insomnia, as proposed by Hartmann in 1977. By use of six healthy subjects, the effects of oral doses of L-tryptophan ranging from 1-6 g or placebos, administered in a double blind study either 20 min before lights out (2300 hr) or at 1400 hr in daytime were studied. The investigators were not able to identify any outstanding effect of any dose of the amino acid when it was given at night, but in daytime studies the 4 g dose resulted in an increase in stage 3 sleep during the first 2 hours but had no effect on sleep onset latency. They concluded that the hypnotic activity of a single dose of L-tryptophan is limited, and that doses greater than 4 g may be required to reduce awakening and increase slow wave sleep. It should, however, be borne in mind that the absence of an effect in healthy subjects in whom no deficit exists does not necessarily imply that L-tryptophan would be equally without effect in insomniacs.

On the 2nd and 3rd days of the meeting there were 76 papers and 56 poster presentations. These dealt with the more fundamental aspects of pharmacologic research, covering an enormous variety of topics. Among these, opiates, endogenous opiate peptides and opiate receptors featured prominently, although no really new and convincing information towards the unravelling of this increasingly complicated field was provided. The group of Prof. H.W. Kosterlitz at Aberdeen found evidence for at least two different binding sites in homogenates of guinea pig brain, one of which recognizes morphine-like ligands and one that recognizes enkephalin-like ligands. I. Marshall, P.A. Nasmyth and D.G.L. Phillips (St. Mary's Hospital Medical School, London) showed opiate tolerance and cross-tolerance developing in the mouse vas deferens preparation, and Gibson, Ginsburg, Hart, and Kitchen (Chelsea College, Univ. of London), using the mouse vas deferens as a bioassay system, found an acute decrease after laparotomy and adrenalectomy and an increase after dexamethasone treatment in the hypothalamus of a substance they assumed to be enkephalin. Unfortunately, the evidence was not overwhelmingly convincing. Work on substance P also featured prominently. A dose-dependent increase in locomotor activity after injection of 50 ng to 3 µg substance P into the ventral tegmental area of mice was reported by S.D. Iversen, A.E. Kelley, and L. Stinus (Univ. of Cambridge). Evidence for the possible coexistence of serotonin and substance P in medullary raphe neurons of rat brain was presented by A. Bjorklund, P.C. Emson, R.F.T. Gilbert, and G. Skagerberg (Univ. of Lund, Sweden and MRC Neurochemical Pharmacology Unit, Cambridge) and J.W. Growcott and J.S. Shaw (ICI Ltd., Macclesfield), who were unable to produce analgesia in mice after the intraperitoneal injection of substance P, as has been reported previously by two independent laboratories.

Among the most interesting papers was that presented by G. Grignani, K. Martin, and G.V.R. Born (Univ. of Cambridge), first confirming that the serotonin content of platelets from normal persons was significantly higher than in platelets from manic depressives, and then going on to show that this is because the specific mechanism for the serotonin uptake and storage capacity is less effective in these patients. In addition, they showed that treatment with lithium causes this abnormality to be fully restored. Since adding lithium to platelets *in vitro* makes no difference to the function of this serotonin uptake system, it would seem that the *in vivo* effect of lithium is indirect. Another interesting paper was presented by B.D. Greenstein (St. Thomas's Hospital Medical School, London) who, using an assay of liver membrane insulin receptors in obese, hyperglycemic (ob/ob) mice, provided evidence that the antidiabetic sulphonylureas may exert their action by increasing liver insulin receptors. In the area of methodological developments, the *in vivo* voltammetry technique presented by G. Curzon, P.H. Hutson, and P.J. Knott (Institute of Neurology, London) for the detection of electroactive material in the caudate nucleus of freely moving rats was by far the most promising. This method is a modification of the electrochemical technique of Adams et al. (1978) for the repeated monitoring of transmitters released from brain tissue *in vivo*, except that it uses linear sweep voltammetry. The effectiveness

of the technique was demonstrated in rats that had been implanted with electrodes in the caudate nuclei 48 hours previously. After establishing the presence of electroactive material at the electrode tip, various manipulations known to alter dopamine release were used. Tail pinch or restraint increased the height of a peak at 0.35 V (v.Ag/AgCl) within 1 min. These procedures also provoked biting, licking, and gnawing. Similar peaks were obtained after the injection of d-amphetamine which releases dopamine directly or α-flupenthixol, which releases it as a result of dopamine receptor blockade, and pretreatment with the catecholamine synthesis inhibitor, α-methyl-p-tyrosine, prevented all these responses. Although this technique is certainly not foolproof and the identity of the electroactive material measured must be established for each experimental condition, it provides a major step forward in the continuous monitoring in freely moving animals of changes in transmitter events that underlie behavioral and physiological functions.

The VIIth Gaddum Memorial Lecture entitled, "The Use of Neuronal Proteins as Markers in Cytopharmacology," was given by Dr. A.D. Smith (Department of Pharmacology, Oxford Univ.). It was an excellent description of the techniques he developed based on the observations that electrical stimulation of the splanchnic results not only in the secretion of catecholamines from the adrenal medulla but also of various protein molecules, such as chromagenins and dopamine β-hydroxylase, that could be used as markers to visualize by electronmicroscopy the process of secretion from vesicles by exocytosis. Unfortunately, the lecture was poorly attended, perhaps because it was in direct competition with a conference at the CIBA Foundation discussing evidence questioning the very existence of vesicles!

On the other hand, the Lilly Lecture entitled, "Analgesic Nephropathy and Hepatotoxicity," presented by Dr. L.F. Prescott (Reader in Pharmacology and Therapeutics, Univ. of Edinburgh), had widespread appeal. The analgesics aspirin, phenacetin, and the active metabolite N-acetyl-p-aminophenol were introduced into therapeutics such a long time ago and therefore did not have to be subjected to the stringent tests that would have been required today for the introduction of a new drug. Numerous toxic side effects have been reported and rediscovered over the years including proteinuria, impaired renal function, bleeding tendencies, gastrointestinal ulceration and bleeding, chronic asthma, hepatotoxicity, effects on pregnancy and labor, and so on. Because they are mostly prescribed as mixed analgesics, the toxic effects of these drugs have not been studied individually to any great extent, and it has generally been assumed that only excessive consumption results in toxic side effects. Prescott first began to study the toxic effects of these drugs on the kidney and the liver in the early 70s. He observed that people who had abused mixed analgesics showed a renal disease characterized by a rise in tubular lesions and renal papillary cell necrosis. He found that even a single dose of 3.6 g/day of aspirin (equivalent to 12 Alka-Seltzer tablets) resulted in a large excretion of renal tubular cells. Phenacetin and N-acetyl-p-aminophenol were much less active. The absorption of these drugs was dependent on particle size and on the preparation. Aspirin/phenacetin/caffeine mixtures more readily produce papillary necrosis than aspirin or phenacetin alone. Antipyrin and amidopyrin also produce nephrotoxicity, as do phenylbutazone and indomethacin. In fact, phenacetin, which has generally been considered the "chief offender," is probably the weakest in this respect. Prescott pointed out that in Sweden, where the use of phenacetin had been banned since 1960, deaths from uremia had not declined. The incidence of hepatotoxicity produced by these drugs is just as alarming. The number of cases of hepatic necrosis that can now be traced to the abuse of aspirin in particular, is ever-increasing. Prescott's contribution has been aimed at determining the mechanisms by which these toxic effects are produced and at developing means of preventing or counteracting them. He, as well as investigators at the NIH (Mitchell et al.), acquired evidence from animal research that the toxicity is due to the depletion of glutathione in the liver. As a result of this observation, various radioprotective agents were tested starting with cysteamine administered intravenously in cases of hepatic coma. It was found to be effective as long as it was given within 10 hours of the

ingestion of the toxic dose of analgesic. Since cysteamine also has unpleasant side effects, it was only given in extreme cases and other sulfhydryl donor compounds were tested. Penicillamine and dimercaprol were ineffective and methionine was only partially effective. The most successful agent has been N-acetyl-cysteine, which is not only very effective but does not have the unpleasant side effects of cysteamine. It is also an effective treatment for the nephrotoxicity produced by these analgesics. Prescott presented a forceful lecture with a message for everyone who has ever taken analgesics—and who hasn't?

British pharmacologists maintained the tradition of asking the session chairman and members, at the end of each paper, to approve publication of the abstract in a special issue of the *British Journal of Pharmacology*. No request was declined, although this has been known to happen. It was overall a well-organized and informative meeting, and for the £2 ($4.00) registration fee that included a Program, Abstracts, morning coffee and afternoon tea, the best value for money in England today. (J. Vernikos-Danelis, Visiting Scientist, Dept. of Pharmacology, Royal Free Hospital School of Medicine, Univ. of London)

PHYSICAL SCIENCES

THE IMPORTANCE OF BUBBLES

It is remarkable how much technology depends on air bubbles. To give just a few examples, there is froth flotation of ores, waste-water treatment, detergency and the manufacture of plastic foams. But all these applications pale in importance to the ageless pastime of children of all ages: blowing soap bubbles. Indeed, it was on this subject that Prof. J. A. Kitchener [Royal School of Mines (RSM), Imperial College of Science and Technology, University of London] began his introductory lecture to a recent symposium on Air Bubbles, Their Interactions and Applications. His first slide showed Sir John Everett Millais's (1829-96) painting of his grandson sitting on a rock, holding a bubble pipe and a bowl of soap water and gazing at a high floating bubble. The painting came to some notoriety when purchased by Thomas J. Barratt in 1888 to be reproduced with a bar of transparent soap at the boy's feet and published as a handbill and newspaper advertisement for Pears' soap. This early use of art for commercial advertising set up a storm of controversy that was still being debated in *The Times* three years after Barratt's death.

Kitchener's lecture and the papers presented in the symposium brought out some of the highlights of a most fascinating area of surface science. The meeting was held in London on 19 December 1978 and was co-sponsored by the Colloid and Interface Science Group of the Faraday Society and the Colloid and Surface Chemistry Group of the Society of Chemical Industry.

In any process that utilizes bubbles, the first consideration is bubble formation. Bubbles form only with great difficulty in pure, homogeneous liquids; nuclei are required, and present theory can predict the critical nucleus size for a given set of conditions. Once formed it is helpful if the bubbles do not coalesce with each other. If there is a surface active agent (surfactant) present, it will adsorb at the air/liquid interface and give the bubble surface an elasticity that resists coalescence. There is probably no barrier to coalescence in pure water, although there is some evidence of an electric double layer which would resist coalescence.

Dr. J. F. Padday (Kodak Research Laboratories, Harrow) presented a paper on the size of bubbles emerging from an orifice, which depends on the orifice radius, the pressure at the point of release, the density and the surface tension of the surrounding liquid, and the depth of immersion. Treating the problem as one in meniscus stability, Padday has developed a relatively simple theory for predicting bubble size which fits experimental results quite well down to bubble radii of ±1000 Å.

The rate at which bubbles rise in water is much faster than predicted if the surface is assumed to be rigid but slower than predicted if the surface is fully mobile. Actually, the interface is mobile, but traces of surfactants, extremely difficult to remove, accumulate behind the rising bubble to create a surface tension gradient (drag) which slows the rate of rise.

The efficiency of particle removal by flotation depends on the bubble collision efficiency, i.e., the number of collisions that result in attachment. Attachment depends on two factors: the rupture resistance of the liquid film between the bubble and particle and the presence of a hydrophobic surface on the particle. The thermodynamic condition for attachment requires that the work of adhesion of water to the solid is less than the work of cohesion of water.

The rupture resistance of the liquid film between a contacting bubble and particle is the most difficult question. Rupture depends on the organization of the water molecules and adsorbed species at the solid/liquid and liquid/air interfaces and the events that occur as these two interfaces approach each other as the film thins, all of which has been the subject of intense research for at least 50 years. It is obvious that adsorbed surfactant can, by imparting surface elasticity, impede rupture. The source of resistance to film rupture in pure water is not so obvious. Kitchener suggested that a "disjoining pressure" may be important. The concept of a disjoining pressure arising because films of liquid a few molecular layers in thickness have a different structure from the bulk liquid was developed by B. V. Derjaguin (Academy of Sciences, Moscow) but has been generally rejected by scientists in the West. However, Kitchener has presented evidence that even against very clean, hydrophobic surfaces a film of water hundreds of angstroms thick can be stabilized by a disjoining pressure controlled by long-range electric double-layer repulsion.

A hydrophobic surface, a surface that water does not wet, generally has a lower surface energy than water, e.g., wax or polyethylene. Kitchener views hydrophobicity as the condition in which water H-bonds to itself more strongly than to the solid. Some minerals are naturally hydrophobic, often because of an adsorbed organic film. In most flotation processes surfactants must be added which adsorb onto the mineral to create a hydrophobic surface. These additives adsorb selectively to either the ore or the gangue.

Kitchener is retiring from the RSM, and in honor of his many contributions to surface chemistry the Colloid and Surface Science Groups presented him with a gift at the end of his lecture.

Oil droplets rising through aqueous mineral slurries are sometimes used instead of air bubbles in mineral flotation, and this was the topic of Dr. H.L. Shergold's (RSM) lecture. One advantage of oil droplets is that they require less area for contact and so capture smaller particles than air bubbles. The oil must be recovered and reused to make the process economical. Another aspect of the oil droplet flotation is that the solid particles can be either extracted into the oil phase, captured at the oil/water interface, or both. Shergold is studying the conditions under which extraction or gathering occurs in the flotation of rutile (TiO_2) particles by benzene droplets in aqueous surfactant solution. He finds that extraction and/or gathering are a function of pH and the type and amount of surfactant, but no clear criteria emerged for predicting extraction vs gathering. It was evident from Shergold's work that simple surface chemical thermodynamics will not predict oil/water displacement processes.

The question of water displacement was the subject of Dr. J. Mingins' (Unilever Research Labs, Port Sunlight) lecture on his excellent work on the attachment of very small, hollow glass spheres (ballotini) to an air/water interface. The experiment involved glass spheres settling to the interface at the end of a column of water in a glass tube (Fig. 1). The water contains a

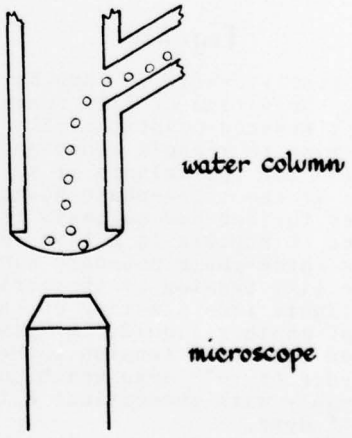

Fig. 1.

low concentration of surfactant. The spheres were observed through a microscope, and with special illumination the distance they penetrated the interface could be measured. The spheres are held in the interface by a balance between gravity and the surface forces acting along the three-phase (air/glass/water) line of contact. The surprising result of the study was that some of the spheres would not penetrate the interface (Fig. 2a). Mingins found that spheres with diameters < 2μm never penetrate and spheres with diameters > 30μm always penetrated. Spheres with diameters between these bounds sometimes did and sometimes did not. He was able to show that the contact angle (θ in Fig. 2b) was the same for the different size spheres and also that neither electrostatic nor dispersion forces were stabilizing the film between glass and air.

Fig. 2a

Fig. 2b

Clearly, there is some barrier to the nucleation of film rupture, which Mingins treated quantitatively as a correction to Young's equation; an expression for the balance of surface forces at the three-phase boundary. He goes further and suggests that the barrier to rupture is a line tension at the three-phase boundary similar to the line tension at the periphery of a liquid lens floating on the surface of another liquid. Mingins calculated this line tension to be of the order of 10^{-5} dyne which compares reasonably with theoretical estimates of 10^{-6} dyne.

Film stability was also the subject of Dr. G. Gonzalez's paper on his research under Prof. R. H. Ottewill (Univ. of Bristol). Gonzalez had measured the thickness of stable films formed when an air bubble is pressed against polished silver iodide plates or cleaved mica sheets submerged in aqueous electrolyte solutions. He finds that the films were too thick to be stabilized by dispersion forces but that their thickness could be reasonably explained in terms of electrostatic forces.

The final paper was given by Dr. A. L. Smith (Unilever Research Labs, Port Sunlight) who strongly argued that, except for getting the correct sign, the true surface charge on air bubbles or at air/water interfaces has never been measured. He includes his own measurements in this sweeping statement. Surface potential measurements on bubbles are usually made using electrokinetic techniques, but this type of measurement presents considerable difficulty because of the size-to-density ratio of bubbles and because of uncertainties about the condition of the interface. The latter difficulties persist when measurements are made at plain air/water interfaces. In his abstract Smith promised to prescribe some remedies but evidently had not thought of any at the time of his lecture.

This writer enjoyed very much an opportunity to attend a conference on "classical" surface chemistry which in recent years has been neglected in favor of the surface spectroscopies. The latter are very powerful tools for studying the gas/solid interface but are incapable of dealing with liquid interfaces. Yet so much technology, especially chemical processing, involves surface chemistry at liquid/solid/air interfaces. But research in this area is not "scientifically popular" at present, perhaps because it does not lend itself to neat, simple models. However, as Padday remarked at the end of his lecture, "There is a theory of capillarity, it is simple and it works." (Willard D. Bascom)

ONRL REPORTS

See the back of this issue for abstracts of current reports.

OCEAN SCIENCES

SPINNING UP A BANK

It has long been known that bottom topography may be related to ocean currents and vice versa. However, detailed relationships for steady conditions are unknown except for a few simple sets of conditions.

Dr. P. Pingree of the British Institute of Oceanographic Sciences (IOS) at Wormley has determined that vorticity in the water which is generated when very strong tidal currents sweep around headlands, jutting out into the current, may be responsible for the formation and maintenance of permanent underwater banks or shoals on one side of headlands but not on the other. He presented the results of his research at the January 1979 semi-annual IOS-Cambridge University Symposium on Fluid Dynamics in Seas and Oceans.

Pingree has developed a nonlinear model of tidal stress in coastal waters around the British Isles for the purpose of studying pollution problems from coastal outfalls.

Amongst others an outfall had been proposed for the tip of Portland Bill, a very prominent headland or cape pointing out into the English Channel southwest of London. He was asked to make a study of the area to determine its suitability for the location of the outfall. This headland is well known for the very strong tidal currents that sweep around it and which at the time of spring tides, when the strongest tidal currents occur, may have velocities as great as seven knots.

Pingree's model can be used to compute the mean residual flow in the vicinity of Portland Bill. His model predicted that the residual currents flow outward, perpendicular to the coast from the region around the tip of the headland and that weaker currents flow landward around two eddies on either side of the tip. However, the instantaneous distribution of tidal currents at any given time is quite different from the residual flow pattern and depends on the stage of the tide and the direction of flow and speed of the tidal currents.

Vorticity is generated off the tip of the headland as tidal currents follow a curved path around it. The vorticity is conserved and, as it is advected downstream with the tidal flow, it results in a nearly circular eddy in the lee, or on the downstream side of the headland. When the tide changes directions from flood to ebb or vice versa, the eddy moves from one side to the other of the headland. When the tidal flow is toward the east, the advected vorticity is positive, which causes the eddy to turn in a counterclockwise direction. The centrifugal force within the eddy acts outward from the center of the eddy perpendicular to the direction of flow at any location around the eddy. At the same time, the Coriolis force associated with the earth turning around its axis acts to the right of the direction of ocean currents flowing in the Northern Hemisphere, and thus both forces are in the same direction relative to the tidal flow and tend to reinforce each other.

The divergent outward movement within the eddy, due to the centrifugal and Coriolis forces, is matched by inflow into the eddy near the bottom. There is a component of stress on the bottom sediments that is pointed inward toward the center of the eddy. This stress moves sediments in toward the center of the eddy during the part of the tidal cycle when the eddy is present on the eastern side of the tip of the headland, and an underwater bank, or shoal, is built up under the eddy. Once the bank is established, a steady-state situation occurs in which the accretion of sediments under the eddy is balanced by erosion during the part of the tidal cycle when the eddy is not present on the eastern side of the headland. This bank on the eastern side of Portland Bill is called the Shambles.

When the flow reverses and the tidal currents are to the west around the headland, an eddy is formed on the western side of the headland. This eddy turns in a clockwise direction. In this situation the centrifugal force is again outward from the center of the eddy, but the Coriolis force is to the right of the direction of flow, or inward toward the center of the eddy. The two forces are in opposite directions, opposing each other, thus reducing the divergence within the eddy to the point where the bottom stress is too weak to build up and maintain a permanent underwater shoal or bank. The end result is a permanent submerged bank on the eastern side of the headland, Portland Bill, with no such bank on the western side.

The eddies on each side of the headland cause a return flow toward the beaches on the sides of Portland Bill, indicating that the headland may not be an ideal place for an outflow containing pollutants. However, it would still be better than releasing the pollutants on the beach, or in adjacent bays, as dilution would occur in the high velocity turbulent spot at the tip of the promontory.

Pingree gave a second example, the Start Point Promontory, also in the English Channel, where a permanent submerged bank is found on one side of a headland, and not on the other. (Wayne V. Burt)

OROGRAPHICALLY INDUCED UPWELLING

Typical coastal upwelling is found in mid to subtropical latitudes on the west coast of continents whenever a steady wind is blowing along the coast toward the equator. Some of the major upwelling areas are found off the coasts of the following regions: Oregon and California, Peru, Western Australia, and northwest and southwest Africa. In each case the Coriolis force associated with the turning of the earth causes a net flow of surface water away from the coastline. This flow is to the right of the wind stress on the surface in the northern hemisphere and to the left in the southern hemisphere. As the surface waters are moved seaward from the coastline, nutrient-rich subsurface waters come to the surface in the process called upwelling. Upwelling areas are very important commercial fishing grounds because the nutrient-rich waters support strong plankton blooms, the first step in the food chain of the fish. For this reason, a great deal of research has been done on the processes involved in upwelling.

However, coastal upwelling is sometimes found in places other than on the west coasts of continents or in the absence of equator-ward winds. Such upwelling may be due to the effects of bottom topography and the configuration of coastline on ocean currents that impinge upon the coastline.

Over thirty years ago Professor Harold Sverdrup (Scripps Institution of Oceanography) gave a seminar on upwelling in which he mentioned that the atypical upwelling frequently found along coastlines was probably induced by changes in underwater topography, but the exact mechanisms were not understood. Little progress was made in the study of atypical coastal upwelling until quite recently when modelers began to produce mathematical models to study atypical or nonclassical coastal upwelling situations. One such model was presented at the 274th meeting of the Challenger Society held in London on 17 January 1979, when Dr. Adrian Gill (Dept. of Applied Mathematics and Theoretical Physics, Cambridge Univ., UK) gave a paper entitled "Upwelling Caused by Changes in Shelf Topography." He used the model to explain the presence of a steady-state upwelling situation that is found at a fixed location off the southeast coast of Africa near Durban, South Africa. The southwestward flowing Agulhas current flows along the coast in this region. The bottom topography here is such that the continental shelf is relatively wide to the north of Durban, becomes narrow to the south of the city and then subsequently widens again further south.

According to Gill's model one would expect changes in the Agulhas current due to the contraction and then broadening of the shelf. Potential vorticity is conserved, and thus knowing the topography, one should be able to calculate the currents from information derived from a single upstream cross section of the coastal currents.

A two-layered model solution, presented by Gill, showed the coastal currents moving out from the coastline where the shelf broadened out again and outcropping of cold water between the current and the coastline.

Surface isotherms off the southeast coast of Africa show the presence of such "upwelled" water. The cause of the atypical upwelling in this situation is purely geometrical. (Wayne V. Burt)

SPACE SCIENCES

OTRAG—PRIVATE ENTERPRISE EXTRAORDINAIRE

While governments debate the pros and cons of investing large sums in reusable launch vehicles such as the Space Shuttle, a "small" private company incorporated in West Germany, is in the process of developing and testing expendable launch vehicles in the Scout, Delta, and Ariane classes. The idea is to provide a launch service on a strictly commercial basis to any user. The political ramifications of such a venture are awesome and have been heatedly debated in many nations of the world. One potential market is third world countries who would like remote sensing capabilities. This article will not attempt to evaluate the political aspects of such a venture but rather to present some of the technical and economic details available on the potential launch vehicles to be built by the private corporation, OTRAG (the Orbital Transport and Raketen AG).

OTRAG launch vehicles are based on the principle of clustering modules of nitric acid/kerosene rockets circumferentially upon the first stage in a parallel arrangement. It is believed that this will permit easy construction of different launch vehicles for a wide range of missions using the same basic building blocks. The cluster rocket modules are all standardized engines. OTRAG claims that costs will be greatly reduced by this standardization and that reliability will be increased. Rockets will be assembled to meet thrust requirements of 2 to 2000 tons, with potential missions varying from low-altitude research to geostationary commercial missions such as communications satellites. The idea is that of Dipl-Ing. Lutz T. Kayser, President of OTRAG, and has the support of one of Wernher von Braun's colleagues, Dr. Kurt H. Debus, who served at Cape Canaveral as the director of the Saturn rocket launch program and is now Chairman of OTRAG.

The individual cylindrical propulsion modules contain both the fuel tanks and engines and permit ready assembly into launch vehicles of various sizes. Each module has a combustion chamber and nozzle, with injector, valves, electrical valve actuator with electronic logic, and its own battery supply. Another feature is the method of control which is achieved by throttling of the individual modules of the engine cluster rather than gimballing of the thrust chambers. This technique has been tested through intensive computer simulations that have shown excellent control behavior. The clustering feature does not leave space between individual engines and thereby avoids the danger of backflow of hot gases between engines during first stage operation. Throttling (up to 50%) is performed by clustering the main engine valves without the intervention of any additional components, a feature that apparently has not been demonstrated before.

Propellant feed is accomplished by using an adiabatic feed system. This involves fuel and oxidizer tanks that are only 60% filled, the ullage volume being filled with compressed nitrogen to the desired starting pressure. As the engine valves open, the nitrogen forces the propellants into the thrust chambers which have radial injection and ablative cooling. OTRAG claims that much is to be gained in reduced costs and improved reliability since all mechanical and electrical components are eliminated.

More than 1,000 tests have been made during the development and qualification period with the test firing in early 1977 of a cluster of 6 standard rocket modules in a DFVLR (German Space Agency) test stand at Lampoldshausen near Stuttgart. A total thrust of about 20 tons was achieved. Since this first static test firing, OTRAG has acquired a launch center in central Africa from the Republic of Zaire. This launch center, in largely uninhabited territory, is roughly one half the size of West Germany itself. The land is on lease until the end of the year 2000 and a free launch has been promised Zaire as part of the agreement. The center has been rapidly developed and now contains a 2100 × 40 m airstrip for transport aircraft with a nearby underground control center and launch facility. Test rockets have already been launched. In May of 1977 a rocket with partially filled tanks ascended 10,000 meters. A four-engine rocket was launched in June 1978, but this went off course immediately. The fault has been traced to a malfunction of a flight trajectory control valve in one of the engine modules, causing offset thrust.

OTRAG expects to have launched a three-stage rocket this March consisting of 48 to 60 standardized kerosene/nitric acid engine modules in the first stage, 12 in the second and 4 in the third. This rocket should place a 100-kg payload in a 300-km orbit, which is similar to the capability of the US Scout. Significantly, 1979 will also be the year of the maiden launches of the NASA Space Shuttle and the ESA Ariane. Before this major OTRAG launch, however, a test of the single-stage four-engine rocket that went off course in 1978 will be undertaken.

In addition to the backing of well-known rocket experts, OTRAG has the backing of hundreds of millions of dollars from private investors and banks. The commercial success will depend on the ultimate ability of OTRAG rockets to place payloads in geostationary orbit at costs competitive with the Shuttle and Ariane. The latter vehicles have government backing and the going could be rough. However, OTRAG insists that their launch vehicles and services will be highly competitive with other systems. For example, they believe that an OTRAG vehicle can place a typical payload (for example an Intelsat 5 telecommunications satellite) in geostationary orbit for $13 million less than the Space Transportation System (Shuttle plus upper stage). Such assertions at this time are probably simply reasonable engineering guesses backed by a strong marketing approach.

As more technical and economic details of the OTRAG system become a available, they will be reported. Whatever the outcome, OTRAG is certainly a unique endeavor and demonstrates that private industry is capable of almost anything if the will and determination is there. Without government sponsorship, OTRAG is an operation in the truest capitalistic sense. (Robert W. Rostron)

NEWS & NOTES

LATE DEVELOPMENTS ON THE EUROPEAN SATELLITE SCENE

The Chinese Academy for Space Technology and the Deputy Chairman of the West German firm of Messerschmitt-Bolkow-Blohm (MBB) have recently signed an agreement for the collaborative development of 10-20 TV broadcast satellites. The satellites will be used for the transmission of educational programs.

The first three will be supplied by MBB and the remaining built by the Chinese. Other West German companies will be partners in the project including AEG-Telefunken, Dornier, Standard Elektrik Lorenz, and ERNO Raumfahrttechnik. The agreement also includes the training of Chinese space engineers at MBB's Munich facility. The first satellites are to be launched in an Ariane rocket about 1983.

Meanwhile, at a Cabinet meeting in Paris, presided over by President Valery Giscard d'Estaing, a decision was taken to proceed with the development and manufacture of two French geostationary telecommunications satellites. The two-satellite system, designated Telecom I, is expected to become operational and the other is being held as a spare.

The project direction is under the French space agency, CNES, and the Direction Generale des Telecommunications. The cost of the program is estimated at about $250 million.

The Cabinet also decided to continue with studies of a direct-broadcast TV satellite designated TDF-1. This program is under the direction of CNES and Telediffusion de France and would also cost in the neighborhood of $250 million.

FELLOWS OF THE ROYAL SOCIETY

Among the forty scientists elected Fellow of the Royal Society on 19 March were the following four Professors of American Universities: John Cowley, Professor of Physics, Arizona State Univ., for pioneering researches in electron microscopy and diffraction, and to theory and technique of high resolution electron microscopy of crystal lattices; Robert May, Professor of Zoology, Princeton Univ., for contributions to theoretical ecology including especially concept of chaos and relations between stability and complexity; Milton Salton, Professor of Microbiology, New York Univ., for studies on isolation and structure of bacterial cell walls and membranes; and David Thouless, Professor in the Engineering and Applied Science Department, Yale Univ., for contributions to the understanding of many-body problem in nuclei and condensed matter,

especially phase transitions and electron localization in disordered systems. Also elected to the Fellowship was Dr. Cyril Hilsum, Senior Scientific Officer, Royal Signals and Radar Establishment, Malvern, UK, (See *ESN* article "Microwave Semiconductors on the Lido di Venezia" on p. 139 this issue), for contributions to science of compound semiconductors and semiconductor devices.

ELECTRICALLY CONDUCTIVE CONCRETE

A requirement sometimes found in the construction of buildings is that floors (or walls) have good electrical conductivity. For example, hospital operating rooms must have anti-static floors; some other buildings should be well shielded against electromagnetic radiation. In the past, this has required expensive installation of metal grids covered by conducting tiles. In an article in the *GEC Journal of Science & Technology* (Vol. 45, No. 1, 1978), J.R. Farrar of Marconi Communication Systems Ltd. describes an electrically conductive concrete, composed of ordinary Portland cement and a carbon by-product of oil refining called Marconite, which simplifies the construction of conducting floors, walls, or ceilings enormously. The material has been certified for acceptance by the construction industry.

NEW JOURNAL

Publication of a new informational technical specialist journal, *Displays—Technology and Applications* has been announced by IPC Science and Technology Press Ltd., Westbury House, Bury St., Guildford, Surrey, England, GU2 5AW. The Editorial Board of 14 includes 10 representatives from the UK and from the US. The journal is to cover the various aspects of electronic display technology.

ONRL REPORTS

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THE SEVENTEENTH (INTERNATIONAL) SYMPOSIUM ON COMBUSTION by S.N.B. Murthy, I. Glassman, and J.R. Patton

The Seventeenth International Symposium on Combustion convened 20-25 August 1978 at the University of Leeds, UK. Sponsored by the Combustion Institute, the Symposium contained three colloquia on coal combustion, turbulent-combustion interaction, and fire and explosion. Papers discussed in this report are in the areas in which advances appear to be stimulating and technologically useful, such as soot, turbulent-combustion interactions, fire and explosion, coal combustion, propellants and explosives, deflagration to detonation transition, kinetics, and new measurement techniques.